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Using Alternating Treatment Design To Determine Math Interventions For Linear Equations

Bridget McKenna

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**Using Alternating Treatment Design to Determine Math Interventions for Linear
Equations**

BY

Bridget McKenna

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Specialist in School Psychology

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
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Abstract

Although algebraic skills are vital to continuing success in higher order mathematics, few studies have examined the effectiveness of mathematics interventions with high school students. The purpose of this study was to evaluate the effects of four mathematics interventions, contingent reinforcement, repeated practice, mathematic problem previewing, and immediate corrective feedback, with six students working on linear equations. Three participants were performing instructional level and four at frustration level. After a curriculum based assessment and baseline, an alternating treatment design examined the effectiveness of each intervention across participants. The distance between the data and the x axis was analyzed to determine the most effective intervention to implement. For all students at the frustrational level and three of the four students at the instructional level, repeated practice was the most effective intervention in improving digits correct per minute. For one student at the instructional level, contingent reinforcement was the most effective intervention in improving digits correct per minute. The results will be further discussed along with limitations and future research.

Using Alternating Treatment Design to Determine Math Interventions for Linear Equations

Algebraic skills are crucial to success in many college programs, employment opportunities, self management and financial decisions to name a few (Usiskin, 1995). Many college majors require that students understand and utilize higher mathematics concepts such as calculus and statistics. The foundation for the aforementioned advanced mathematics is largely rooted in algebra. Thus, many states have made algebra a high school graduation requirement (Chambers, 1994).

An example of an algebraic problem is linear equations. Linear equations involve change at a constant rate. They can be applied to “total cost of items when each item costs the same, total calories or vitamins or minerals consumed in food, total amounts of material in producing object...cost of household bills, cost of renting a car, cost of a long-distance call,” (Usiskin, 1995, pp. 33).

There has been a fair amount of research on math intervention strategies with children. Unfortunately, most of these interventions focus on basic arithmetic. Very few studies have been published on higher order math problems. Early intervention is vital to remediate deficits in math skills; however, there are many students who struggle daily with higher level math concepts. Adolescents in high school are generally not participants in the math intervention research; yet these are the students who may need the most urgent interventions due to their impending graduation.

For the purpose of this review, several key aspects will be discussed to lay the foundation for future research. First, the types of models for learning academic skills will be reviewed to provide a context in which the supporting literature has been grounded.

There are two areas to the supporting literature, reading and mathematics. The interventions, designs, and measures of reading are relevant for the mathematic literature due to the plethora of supporting evidence. It is important for the reader to understand that much of the mathematic literature was based upon the findings in the reading research. However, both the reading and mathematics literature demonstrate weaknesses (i.e., lack of model adherence, intervention selection, narrow scope of participants, measurement, and design issues) that should be highlighted for further discussion.

Models of Learning Academic Skills

There are two predominate models in the school psychology literature on learning academic skills. The first is the Instructional Hierarchy (IH) proposed by Haring and Eaton in 1978. They propose four stages in which a learner moves throughout the learning process. The IH model will be outlined and supporting research of the efficacy of the model will be provided. The second model proposed by Daly, Witt, Martens, and Dool (1997) suggest that students are grouped into to broad categories, skill building or motivation building. Again, the review will outline the model as well as supporting literature.

Instructional hierarchy (IH). There are four stages that are conceptualized as an instructional hierarchy by Haring and Eaton (1978). In order for a student to enact a new behavior, he/she must first acquire the behavior, then perform the required behavior fluently, then he/she must be able to generalize and finally adapt the skill to new circumstances. Students progress through these stages when learning new material. Certain interventions may be more effective depending on which stage a student is in the instructional hierarchy. Students may perform in different ways as they progress through

each stage (Eaton & Harding, 1978). It is important to first conceptualize what each stage entails.

Acquisition involves first demonstrating the steps that lead to a new skill. Until a student responds to a task accurately it cannot become an acquired skill. Demonstration and modeling have been used to help students acquire unknown skills (Eaton & Harding, 1978). Once a skill has been acquired the student can then move on to increasing the fluency or proficiency of the skill. Producing the skill competently is important if the student wants to apply the skill to different areas. Drills, active repeated responding, and reinforcement of accurate responding can increase fluency (Eaton & Haisch, 1974).

Students who have acquired a new skill and can fluently respond must learn how to do so in novel situations. Generalization involves responding accurately even when the stimulus changes. Practice is often recommended to increase generalization of new skills (Eaton & Harding, 1978). Practice involves applying the learned response with other learned responses to solve problems. Two types of practice are discrimination and differentiation. Discrimination involves teaching students to emit one type of response when certain stimuli are present but not when other stimuli are present (e.g. multiplying when x sign is present, but dividing when / sign is present). Differentiation can occur when a student is reinforced for responding to various stimuli which have slightly different aspects (Eaton & Harding, 1978).

The final step in the IH is adaptation. Once a student has generalized the skill to new situations, he/she must then learn to adapt or modify the response to apply it to other problems. Adaptation is the most complex step in the hierarchy and cannot be easily taught (Eaton & Harding, 1978). Teachers can help students adapt new skills by

providing them opportunities to practice their skills in many new situations. Acquisition can be developed through problem solving as well as simulations (Eaton & Harding, 1978). Instructional hierarchy can be used to select instruction interventions.

Supporting reading research. O'Shea, Munson, & O'Shea (1984) compared the effectiveness of individual error word drill with phrase drill. Individual error word drill involves having the student repeat their error word multiple times before continuing to the next sentence, while phrase drill involves the student repeated the entire phrase of words multiple times before continuing. The researchers hypothesized that phrase drill would improve reading accuracy in context/and or isolation more than word drill. Reading in context involves students repeated the phrase or word during the story, while isolation involves repeated the phrase or word after the story has been completed. They also hypothesized that phrase drill would be more effective in improving fluency than word drill. Five participants, three females and two males, were referred for learning disabilities in reading. They ranged in ages from 7 years old to 11 years old. One-hundred word passages were taken from two basal reading series. The participants were assessed on their reading fluency and reading accuracy. Fluency was measured by words read correct per minute (WCPM). Accuracy was assessed by examining the number of error words each participant read correctly in isolation and in the context of the reading passage. Phrase drill was a more effective procedure to improve accuracy of error words read correctly. However, there were no significant differences regarding fluency between phrase drill and word drill. Thus, the findings may suggest that phrase drill may be an appropriate intervention for children who are at the acquisition stage in developing new skills.

Rashotte and Torgesen (1985) examined whether the percentage of word overlap across passages would increase reading speed, word accuracy and comprehension of students. The participants were 12 students who had reading disabilities with a mean age of 10.5 years. Students read 44 different passages with a stated Grade 2 level of readability. Thirty-seven of the passages had only 20 words that were common to three or more stories in a condition. The participants were in either condition 1 or 2 or 3. Condition 1 and 2 were the two repeated reading conditions, while condition 3 was non-repetitive reading condition. The researchers measured each students' words read correctly per minute (WCPM; fluency) number of errors made in each reading (accuracy) and the percentage of comprehension questions correctly answered. They found that participants had great reading speed on stories that had many shared words. However, the percentage of word overlap did not significantly affect the number of words read nor the numbers of errors made by each participant. Results suggest repeated readings increase fluency but also that passages containing word overlap aid in a student's generalization of skills.

Daly and Martens (1994), examined which interventions corresponding to the IH were the most effective for reading performance. The participants were four male students with learning disabilities in reading. The average age of the participants was 10 years 8 months old. The participants had a mean Full Scale IQ standard score of 93.5 (mean of 100, standard deviation of 15). The average reading achievement standard score across participants was 71 (mean of 100, SD of 15). Modeling (acquisition), drill (fluency), and criterion stimulus condition training (generalization) were used. Passage previewing, taped words (the participant listened to a tape of the vocabulary words),

subject passage preview, listening passage preview (research read the passage to the participant), and taped words procedures were used. Taped words and listening passage preview have an acquisition element. Subject passage preview and listening passage preview have a fluency element. The listening passage preview intervention has a generalization component. The researchers measured accuracy and fluency on passages and the word lists.

They found that participants in the listening passage preview conditions had the largest increase in accuracy and fluency in the passages. This may be due to the fact that listening passage preview combines “modeling plus drill criterion stimulus conditions for the target academic behavior,” (Daly & Martens, 1994, p. 467). They suggest that the level of the reading material may have been inappropriate for some of the participants; this may have dampened the effectiveness of the interventions on fluency and accuracy.

In summary, Ardoin and Daly (2007) discussed the importance of IH when selecting interventions. They believe IH has helped practitioners implement academic interventions by paying attention to how students are responding. They believe IH has taught practitioners how to change the interventions when one observes students’ changes in responding. Teachers need to emphasize instruction that shows students how to accurately respond. They can facilitate this through modeling and error correction. Fluency can be increased through opportunities for correct responding with timed trials and performance feedback (Ardoin & Daly, 2007). Students are more likely to learn how to generalize their new skills when they are accurate and fluent in their responding. Students who are struggling with generalization may need to refocus on increasing fluency and accuracy.

“Proficient performance of any skill involves multiple dimensions which include accuracy, accurate rate, accurate rate under more demanding training conditions, accurate rate under conditions different from training and spontaneous modification of the skills to meet novel demands,”(Martens & Eckert, 2007, p. 84). The researchers believe further investigation is needed to determine the effectiveness of different interventions on developing each skill, strategies to reinforce multiple skills at the same time and the relationship between the evolutions of each skill. The effectiveness of interventions at varying levels of instruction will aid teachers in selecting which interventions are most appropriate for students at specific skill levels.

Although IH has influenced much of the research on reading interventions, there has been little if any research examining which interventions are the most effective for students at which instructional level. In addition, mathematic research has not been conducted using the IH model. All previous research has placed students in the instructional hierarchy post hoc. The studies have experimented on which intervention is successful and then placed students into the hierarchy based on the results of the data. By assessing which level of the IH a student is in a priori to the experiment practitioners will be able to more efficiently select interventions that are the most effective with students at that instructional level. Finally, if the research in reading can be expanded upon in mathematics using the IH in a priori fashion, then additional support may be garnered for the model.

Daly, Witt, Martens, and Dool’s (1997) model. Students often have difficulty with academic work for five major reasons according to Daly, et al. (1997). Either the student does not want to do the work, or he/she has not had enough practice doing the

work, or he/she requires more assistance to do the work, or he/she does not have knowledge to perform the skill in that situation, or the work exceeds his/her knowledge level and it is too difficult for them. Providing students increased practice time with that problem can improve their fluency, which improves their accuracy, which leads to a generalization of skills (Daly, et al., 1997). Such techniques such as modeling, prompting, and error correction can improve accuracy of responding, while techniques that provide the student opportunities to practice and reinforce for rapid responding can improve fluency (Daly, et al., 1997; Martens, Witt, Daly, & Vollmer, 1999). Researchers and practitioners can utilize an experimental analysis to test one's hypothesis of why the student is having academic difficulties (Daly, et al., 1997). Brief testing conditions can determine the function of the problem behavior. A multi-element design involves many reversals of treatment conditions. It can be used to determine the effects of different levels of a variable. The variables change sometimes each session and sometimes within the session (Hains & Baer, 1989). The advantage to multi-element design is that it allows researchers to compare variables in the natural environment in which many other variables exist. Multi-element design is best for comparing variables that produce visible effects on the dependent variable rapidly.

Brief experimental analysis and other supporting research in reading. Brief experimental analysis (BEA) involves briefly manipulating two or more alternative treatments and assessing their effectiveness in a single study. Performing a BEA requires four steps. First baseline data must be gathered for the targeted skill, and then empirical interventions must be selected with consideration made to the stage the student is in the instructional hierarchy. Then, the interventions are briefly and sequentially introduced.

Finally, the results of each intervention are compared to each other and the most effective intervention is then implemented and its impact measured (Kuhn, Watson, Ota, Cole, & Johnson-Gros, 2009).

BEA fulfills requirements of the No Child Left Behind Act and the Individuals with Disabilities Education Act. These legislations encourage the use of interventions that are scientifically valid. Practitioners who utilize BEA may also identify fewer children for special education by selecting appropriate academic interventions for them early on.

BEA has been used to examine the effectiveness of strategies used to increase accuracy and fluency in reading and math. BEA can be conducted quickly and is therefore advantageous for use in the classroom. Very little time is lost deciding which intervention to utilize since multiple interventions are assessed quickly. The most effective treatment can then be implemented with confidence because the practitioner already knows the student responds to this treatment. BEA often involves measuring frequency or rate through the use of curriculum-based measurement (Martens, Eckert, Bradley, & Ardoin, 1999).

Passage previewing has been shown to be an effective reading fluency intervention. The practitioner has the student practice reading a passage before the assessment, or the practitioner reads the passage before the assessment or the student listens to a recording of the passage before the assessment (Martens, et al., 1999). Passage previewing is considered to be a drill condition, although it also has modeling and generalization aspects. When a passage is previewed to a student, the student is hearing the passage read by a fluent reader, this fluent reading is modeled to the student.

Eckert, Ardoin, Daisey, & Scarola (2000) utilized a single case design to examine the effectiveness of seven oral reading fluency interventions. The four male participants were referred for reading difficulties by their classroom teacher. All participants were in the general education classrooms. They assessed words correct per minute (WCPM) for each participant. The skill based intervention condition utilized listening passage preview and repeated readings. The performance based interventions were goal setting and performance feedback, contingent reinforcement and the blend of goal setting with performance feedback and contingent reinforcement. After reading each passage the student was told his reading time and his number of errors. The student then graphed his data on a bar graph. The combined skill-based and performance base interventions were skill based intervention with goal setting and performance feedback; skill based intervention with contingent reinforcement; and skill based intervention with goal setting and performance feedback and contingent reinforcement.

Eckert et al. (2000) found the best intervention was different for each participant. Despite the lack of consensus on one effective intervention, the researchers were able to demonstrate the effectiveness of BEA in selecting appropriate reading fluency interventions for each participant. Combining interventions may improve oral reading fluency greater for some students than providing one intervention at a time.

Eckert, Ardoin, Daly, and Martens (2002) examined which is more effective in increasing reading fluency, contingent reinforcement or performance feedback with antecedent intervention. The participants were six elementary school students, three girls and three boys. Two of the boys, Hunter and Stephen, had difficulties in word decoding as well as comprehension. Of the other students, Bethany, Mason, Alison and Vilna,

only Alison and Vilna had mastered their grade level reading material. The reading passages were from first, second and third grade levels. The participants read the passages and their WCPM were recorded. During each intervention the participant read their reading passage three times. The third time he/she read the passage, he/she recorded his/her WCPM.

During the antecedent intervention, the experimenter read the passage out loud and then practiced reading the same passage out loud for three consecutive trials with the student. During the antecedent intervention and contingent reinforcement condition, the antecedent intervention was first performed and then prior to the last reading the participant chose a reinforcer. The researcher told the participant that he/she would receive this item if their final reading WCPM exceeding their first reading by 5% (Eckert et al., 2002).

During the antecedent intervention and performance feedback, the experimenter and the participant developed reading goals before they began the antecedent intervention. During the antecedent intervention, performance feedback and contingent reinforcement all of the previously mentioned procedures were combined and the students recorded their performance on a graph. The baseline and treatment conditions were alternated (Eckert et al., 2002).

No participant increased their performance to a greater extent when the two consequences (antecedent and contingent reinforcement) were combined. For Vilna and Bethany, the antecedent intervention was by itself enough to improve reading fluency. In the other four participants, combining any intervention with the antecedent intervention showed the greatest improvement in oral reading fluency. Stephen's reading fluency was

most increased when contingent reinforcement was added. Mason's and Hunters' reading fluency increased only with performance feedback (Eckert et al., 2002).

Noell, Witt, Freeland, Dufrene, and Gilbertson (2004) argue that traditional assessments "reduce intervention planning to a best guess or trial-and-error procedure, which is inefficient for both students and educators," (pp. 430). They suggest using BEA to examine academic issues and select effective treatments. The researchers used math, reading, and writing probes for the experiment. The four participants were all male, African-American, with ages ranging from 8 years old to 10 years old. The reading passages selected were scored using the Flesh-Kincaid readability index. Math problems consisted of 2-digit-by-2-digit multiplication and 3-digit-by-3-digit multiplication. The dependent variable in math was digits correct per minute (DCPM), and in reading and writing words correct per minute. The amount of academic work attempted was measured during a 10-minute session.

The teachers administered Curriculum Based Measurement (CBM) probes before the intervention as a baseline (Noell, et al., 2004). An out of class assessment was done to see if rewards would increase the students' accuracy on the academic tests. If the students exceeded their goals for each probe they were offered a reward. The researchers hypothesized that if students' performance increased by 50% or more when they were offered a reward the student must have a performance deficit. If the reward did not improve performance, researchers suggested that the student must have a skill deficit.

An alternating treatment design was performed to identify the most effective treatment (Noell, et al., 2004). The treatments focused on skill enhancement and motivation through pre-session practice and guided advanced organization. For

performance deficit, they focused on goal setting and rewards. Two students increased their accuracy when given instruction, this lead the researchers to conclude that the students had a skill deficit. Two different participants increased their accuracy when given a reward leading researchers to conclude that those children had a performance deficit.

Kuhn et al. (2009) examined the effectiveness of reading interventions utilizing a BEA procedure. The researchers measured WCPM, accuracy on maze passages, accuracy on comprehension questions, and treatment acceptability and outcome evaluation (using the Parent Social Validity Checklist). The researchers used instructional passages that contained at least 150 words. A generalization passage with high content overlap (HCO) was constructed that contained 80-90% of the same words presented in the instructional passage. The researchers also created maze passages from the instructional passages. Five comprehension questions were also created. The participant was one 7-year-old Caucasian female. After establishing baseline, the following treatment conditions were utilized: contingent reinforcement, repeated reading, listening passage preview, and phrase drill.

The researchers found that the student read the highest number of WCPM in the repeated reading condition. Listening passage preview and phrase drill were also effective. The contingent reinforcement condition elicited the lowest WCPM score, leading the researchers to believe the student was suffering from a skill deficit not a performance deficit. The student also had high reading performance on HCO passage, maze and comprehension questions in the repeated reading phase. The researchers suggest further study needs to be conducted on the impact difficulty level of material.

There are few studies that examine how varying levels of difficulty can impact interventions (Kuhn et al., 2009).

Common reading fluency interventions tested in BEA's include: contingent reward, performance feedback, student passage preview, listening passage preview, repeated reading, and phase drill (Burns & Wagner, 2008). The variability in the studies of the effectiveness of BEA, the type of passages used and the criteria for indentifying effective interventions are all aspects that make applying BEA difficult (Burns & Wagner, 2008). Burns and Wagner (2008) performed a meta-analysis of the research on BEA in reading to determine what effect size was needed to identify the most effective intervention in BEA, what effects were attributed to interventions used in BEA and how HCO and instructional passage affect inventions used in BEA. The researchers included 13 studies that used BEA, involved children in second through sixth grade, were published in peer reviewed journals, used alternate form passages, were written in English, and included quantitative data that could be analyzed for percentage of non-overlapping data and effect sizes. The 13 studies were categorized into one of two categories, instructional passage or HCO.

Burns and Wagner (2008) found less variability in the HCO passages than in the instructional passages, although there was a larger effect size for the instructional level passages. The researchers found for all studies an average non-assumptions effect size of 2.80 and a percentage of non-overlapping data of 80%. The mixture of the following interventions showed the largest effect sizes: listening passage preview, repeated reading, and performance feedback with or without incentives. The blend of passage feedback, easy material, listening passage preview, repeated reading and incentives; the

combination of listening passage preview, repeated readings, incentives and contingent reinforcement; the grouping of listening passage preview, repeated readings, and passage feedback, with and without incentives, the combination of student passage preview and repeated readings, and the combination of unknown word preview and repeated readings all had over 80% percentage of non-overlapping data, and therefore are considered effective interventions (Burns & Wagner, 2008).

The literature on mathematic interventions is heavily influenced by the interventions, designs and measures in reading. Daly et al.'s model is also applied to mathematics interventions. Many of the following studies use drills, practice, modeling, demonstration and problem solving to increase fluent and accurate responding to basic math facts. However, the literature in mathematics is less coherent in understanding and applying a particular model to understand the learning process.

Mathematics interventions

Students who struggle with math fluency may see improvement when provided with multiple opportunities to practice those skills. An efficient way of increasing responding rates involves timing procedures. Some timing procedures include: time limits, providing feedback on rates of responding, and reinforcing higher rates of responding (Rhymer, Dittmer, Skinner, & Jackson, 2000). Because the goal is high rates of correct responding, it is often helpful to have another person (teacher, computer, aide, and peer) provide corrective feedback to the student when he/she makes an error. It is also advantageous to have the student practice making those correct responses a number of times after making an incorrect response.

Rhymer, et al. (2000) examined the effectiveness of the following interventions in increasing math fluency for four 4th grade students: timings, peer tutoring, positive-practice overcorrection, and performance. Three of the participants were African American and one participant was Caucasian. The participants were nominated by their teachers because they scored below the 25th percentile in mathematics on the Iowa Test of Basic Skills. The researchers utilized an alternating treatment design with the four participants. During the experiment each student was in all three conditions, meaning he/she was a tutor to another participant, he/she was a tutee, and he/she was also in a control condition. The dependent variable was problems correct per minute on each sheet. Three of the four participants had small increases in their problems correct per minute after the timings and positive practice overcorrection interventions. The researchers believe the results showed that explicit timing, active responding, and overcorrection increased the participants problems correct per minute to a greater degree than simply providing feedback on their peers' responses. Encouraging students to beat their previous scores also seemed to increase math fluency.

Many math interventions have been shown to increase fluency and solve motivational problems in students. Carson and Eckert (2003) used a BEA to examine which math computation fluency interventions would be the most effective. The researchers also tested if student selected interventions would elicit greater improvements in computational fluency than empirically selected interventions. Three male students in fourth grade were identified as having a performance deficit in mathematic computation. Each student was in the fluency stage of the instructional hierarchy. Each student had low responding rates but high accuracy rates. The dependent variable was DCPM. The

interventions for this study were: contingent reinforcement, goal setting, feedback on digits correct per minute, and timed sprint intervention.

Carson and Eckert (2003) found that empirically selected interventions implemented after a BEA had the greatest impact on computational fluency for the participants compared to interventions chosen by the participants themselves. These results contradict previous research about choice interventions. The researchers believe this may have been the result of the populations selected for previous studies. The current study utilized participants who were not in special education. Previous studies on choice interventions examined the effectiveness with participants who were severely developmentally disabled.

Maccini, Mulcahy, and Wilson (2007) suggest that although U.S. students have made some improvements in math performance on basic computational problems, they still are behind their international peers in higher order math concepts and problem solving. These conclusions were drawn from the 2003 survey conducted by the Program for International Student Assessment. The researchers performed a review of current mathematics interventions for secondary students, specifically those with learning disabilities in mathematics. The 23 studies identified were published in peer reviewed journals between 1995 and 2006, included students in grades 6-12, and utilized a single subject or group design. The studies were grouped into three categories, behavioral interventions, cognitive interventions, and alternative delivery systems.

The behavioral interventions consisted of a teacher modeling a skill, providing feedback, and reinforcing for appropriately demonstrating the skill. They utilized drill and practice procedures, direct instruction, interspersal technique, and concepts based

instruction. The cognitive studies involved mnemonic devices, increasing instructional sequences, problem-solving strategy, self monitoring, and self instruction. The alternative delivery systems involved contextualized instruction (via video disc), and peer mediated instruction.

Maccini et al. (2007) found that mnemonic strategy instruction, graduated instruction approach, planning, schema based instruction, contextualized videodisc instruction, modeling, guided practice, independent practice, monitoring student performance, and corrective feedback all showed significant effect size and increased student performance in decimals, fractions, geometry, integers, and linear equations.

Class wide peer tutoring (CWPT) may be an effective way to teach higher order algebra problem solving skills. Allsopp (1997) utilized a problem solving skill instruction program called Solving Division Equations: An Algebra Program for Students with Learning Problems. The researcher found that this program was effective in increasing correct responding of basic algebra equations as well as individual student practice. Allsopp (1997) implemented a class wide peer tutoring system in 14 different general education classes with 262 students. The participants' ages ranged from 12 years of age to 15 years of age.

The intervention program implemented consisted of three learning strategies, which involve mnemonic devices to remember steps to solve problems. The program also utilized concrete manipulative in the beginning lessons and progressed into more abstract ideas towards the end of the 12 lessons. The different classrooms were randomly assigned to either Treatment Group A (independent practice) or Treatment Group B (CWPT). The results showed that neither treatment was significantly more effective than

the other. The problem solving skills instruction program was effective with participants both conditions. Allsopp (1997) believed the results were important because they had demonstrated that CWPT was as effective as independent practice for increasing higher order math skills. The researcher cited the amount of time needed to implement CWPT as a concern.

Cover-copy-compare (CCC) and performance feedback have also been shown to be effective in increasing academic fluency (Skinner et al. 1993; Struthers, Bartlamay, Bell, & McLaughlin, 1994). The students were taught to look at a problem and the solution on the left side of the page, the student then covered the problem and the solution, then he/she wrote the problem and the solution, then the student compared his/her answer to the correct answer on the left hand side of the page (Skinner et al., 1989). Coddington, Eckert, Fanning, Shiyko and Solomon (2007) evaluated the effects of combining CCC and two types of performance feedback (digits correct per minute and digits incorrect per minute).

Three sixth grade students served as participants. They were referred by their teachers for difficulties in math calculation fluency. None of the participants had been deemed eligible for special education assistance. The participants' mathematics skills were assessed with a curriculum based assessment in mathematics. They received the intervention for approximately 15 minutes, three times per week for 16 weeks. The three intervention conditions were CCC, CCC and performance feedback using digits correct per minute (DCPM) and finally CCC and performance feedback using digits incorrect per minute (DIPM).

Codding et al. (2007) implemented the interventions for each participant using an alternating treatment design once a stable baseline had been established. The researchers measured each participant's DCPM and DIPM. The data did not differentiate between the treatment conditions. The researchers were not able to determine if adding performance feedback greatly improved the scores of any of the participants. The researchers suggest this could be due to performance generalization or that CCC may have some components of performance feedback built into the intervention. There were also no differences in scores between performance feedback DCPM and performance feedback DIPM.

Poncy, Skinner, and Jaspers, (2006) utilized an alternating treatments design to compare the effectiveness of two interventions designed to increase math accuracy and fluency. The interventions implemented were cover-copy-compare (CCC), and taped problems (TP). By increasing student math fact fluency and accuracy they suggested that students will then be able to move on to more multi-step advanced math problems. CCC was used by Skinner et al. (1989) to improve math fluency and accuracy. The TP intervention involves a student listening to a recording of a person reading math fact problems. The student is told to try to write down the correct answer to that problem, before the person on the recording reads the correct answer. These problems are repeated several times to increase fluency and accuracy in responding.

Poncy et al. (2006) utilized CCC and TP with a 10 year old female student who had a Full Scale IQ standard score of 44. The researchers recorded her digits correct per minute (fluency) and the percentage of digits correct (accuracy). Results showed that TP

was equitable to CCC for increasing math fact fluency and accuracy. The researchers note that TP required less time to implement.

Automaticity in math facts (the ability to recall a math fact within 3 seconds of its presentation) is vital to develop skills to solve higher order math problems such as factoring algebraic equations or finding common multiples (Woodward, 2006). Students who struggle with math often lack automaticity (i.e., fluency) in their math facts. These students may require direct explicit instructional strategies to learn these facts. Timed practice drills are one way of developing automaticity in math facts.

Woodward (2006) examined the effectiveness of integrated teaching approach compared to timed practice drills. Fifty-eight students from fourth grade classrooms participated in the study. Twenty-percent of the students were receiving special education services in math. Participants in the integrated group were taught multiplication fact strategies such as derived fact or doubling and doubling-again strategies, and the partial product algorithm. Participants in the timed practice group were taught using direct instruction and the traditional multiplication algorithm. Participants were taught in the groups 25 minutes each day, five days a week for 4 weeks. The results suggest that the integrated group and the timed practice group were both successful in increasing their automaticity of multiplication facts. The integrated group performed significantly better on the Extended Facts and Approximation tests than the timed practice group. Neither group achieved mastery of the facts.

Rhymer, et al., (2002) found that an explicit timing procedure increased the number of math problems students completed. Fifty-four students in sixth grade participated in the study; the mean age of the participants was 11.5 years old. Students

were given a one-step addition problem sheet, three digits minus three digits subtraction problem sheet, and three digits multiplied by three digits multiplication problem sheet. During the first three sessions, the participants completed the sheets untimed. During the next three sessions, the participants had to complete each sheet in only three 1-minute intervals. The participants completed more addition and subtraction problems in the timed condition than they did in the untimed condition. However, the explicit timing procedure did not increase the accuracy of responding, as there were no significant effects found for timing. The researchers suggest that explicit timing should only be used for simple step mathematics problems.

Appropriate measurement (i.e., progress monitoring or the dependent variable) needs to be meaningful and measureable. In addition, the dependent variable has to be sensitive enough to detect change: thus, the dependent variable is as important as the validity of the treatment. Without reliable and valid tools for progress monitoring, practitioners cannot make accurate decisions regarding treatment.

Measurement

Curriculum-based measurement was developed to assess student progress and growth over a period of time in academic subjects such as reading, writing, spelling, and mathematics. It is currently widely used to evaluate students' response to intervention (RtI) in the schools. The Individuals with Disabilities Education Improvement Act contains an RtI provision in which CBM data could be used to make high-stakes decisions (Christ & Silberglitt, 2007). The researchers argue it is necessary to examine the reliability and validity of CBM especially if it will be used to diagnose or place students in special education.

Reading. Hintze and Conte (1997) compared the criterion related validity of CBM using authentic and literature based basal reading materials. The researchers hypothesized that there would be no significant differences between the two reading materials. Fifty-seven students participated in the study. The students were in 2nd, 3rd, and 4th grade classrooms. Words read correctly per minute and scores on the degrees of reading power test were measured. The results suggest that a significant portion of the variance observed in comprehension can be attributed to oral reading fluency scores. The researchers state that in 66% of the cases, scores on reading comprehension measures were predicted from oral reading fluency scores. The researchers also found no significant differences in the criterion related validity of literature based and authentic based basal reading materials. Overall, Hintze and Conte (1997) suggest CBM oral reading fluency measures provide a valid assessment of reading skills, also practitioners can use authentic basal reading materials and have valid scores.

Hintze, Owen, Shapiro, and Daly (2000) argue that there is evidence of reliability and validity in curriculum-based measurement when examining it with the generalizability (G) theory. G theory is a statistical technical designed to assess behavior measurement technical adequacy. It is an alternative to classical test score theory. G theory allows for the proportions of variance to be explained by environmental arrangements and contexts. Hintze et al. (2000) results suggest that practitioners can be confident in making inter-individual decisions with CBM across 16 progress monitoring sessions. The researchers noted that the difficulty level of the probes used for progress monitoring has an impact on the CBM outcomes.

Poncy, Skinner, and Axtell (2005) used generalizability theory with 37 third grade students to examine the reliability and standard error of measurement (SEM) of WCPM using curriculum-based measurement. Specifically the researchers were interested in discerning how much variance in students scores come from student skill, passage, difficulty, or other error. They also examined how changing the probes would affect the standard error of measurement. Results showed that approximately 81% of the variance in WCPM came from the participant's reading skills, 10% of the variance could be attributed to the passage difficulty, while 9% of the variance came from an unknown source. The researchers also found that increasing the number of probe sets decreased the SEM. Poncy et al. (2005) recommend decreasing error by "using sets of five probes that have been field tested and shown to deviate less than +/- 5 WCPM from the set average," (pp. 335).

The reliability in oral reading fluency and maze scores is often measured in terms of alternate forms of these measures. High correlations between forms indicate good reliability (Busch, & Reschly, 2007). Research has found reliability coefficients on oral reading fluency to range from .82 to .87 (Marston, 1989); maze reliability coefficients range from .61 to .91 (Shin, Deno, & Epsin, 2000). There is also evidence for the criterion related validity of oral reading fluency with other reading measure, for example standardized test scores. The coefficients range from .63 to .90 (Marston, 1989).

Fore, Boon, and Martin (2007) examined the concurrent and predictive validity of 50 students' scores on Oral Reading Fluency (ORF), Maze, and Written Retell (WR). The participants were in 6th through 8th grade. All had emotional and behavioral disorders. Their CBM scores were used to predict their Criterion-Referenced

Competency Test (CRCT) scores. Fore et al., (2007) found that only Maze and ORF significantly predicted scores on the CRCT. CRCT scores were better predicted by Maze than ORF. However, ORF had the highest correlation with CRCT.

Christ and Silberglitt (2007) sought to establish the standard error of measurement (SEM) across 8,200 elementary students using reading fluency probes. The results showed an overall median range of reliability of .88-.96. The median SEM across grades was 10 words read correctly per minute (WRCM). The researchers state that CBM scores can be influenced by who is administering the probe and the location of administration. The variability in difficulty across and within the probes can all influence CBM scores.

Math. DCPM has been show to be more sensitive in measuring growth than accuracy measures, therefore it is the primary measure assessed during CBM (Christ, Johnson-Gros, & Hintze, 2005). CBM is often relatively or absolutely interpreted to make decisions. Relative interpretations of CBM involve making screening, placement and grouping decisions. Absolute interpretations of CBM mean making criterion-referenced decisions such as benchmarking, proficiency, or placement in special education or general education (Christ, et al., 2005). In order for practitioners to be confident in their decisions, the technical adequacy of CBM must be assessed. Christ, et al. (2005) examined how the amount of time of each assessment influences the reliability of digits correct per minute in multiple-skill computation assessments.

The 104 general education students who participated in the study were in fourth or fifth grade (Christ et al., 2005). The fourth-grade CBM probes contained addition and subtraction of whole numbers, and multiplication and division of whole numbers. The fifth grade probes contained some of the item types in fourth grade and addition and

subtraction of fractions with unlike denominators (Christ, et al., 2005). The results indicated 60% of the measured variance in multiple one-minute assessments was error variance. Only 17-26% of the variance was attributed to student skills, 5-19% of the variance was attributed to how long the assessment was (1-6 minutes in length). The researchers suggest that the measurement error can be decreased if larger samples of behavior are measured for each student. Large stake decisions (e.g. diagnosis, or placement) should be made by examining large samples of behavior, while low stakes decisions (e.g. benchmarking) can be made by examining smaller samples of behavior (1-min administration) (Christ et al., 2005).

Calhoon (2008) performed a literature search and found only four studies that examined the use of CBM in mathematics at the middle school level. The researcher found only one study that examined CBM in math at the high school level. Calhoon & Fuchs (2003) found CBM to be an effective motivator in high school students to increase their scores. The lack of research on the effectiveness of CBM in high school students is alarming. Calhoon, (2008) states, “we cannot continue to ignore our secondary teachers in their efforts to provide the best possible mathematics education for our high school students,” (p. 238).

Foegen (2008) examined the alternate form, test re-test reliability, predictive and concurrent validity of six progress monitoring mathematic systems for use with middle school students. Five-hundred sixty-three students from grades 6th, 7th, and 8th participated in the study. The six math systems were MBSP Basic Math Computation (MBSP-Comp; Fuchs et al., 1998), MBSP Concepts and Applications (MBSP ConApp; Fuchs et al., 1999), Basic Facts, Estimation, Complex Quantity Discrimination, and

Missing Number. The Iowa Test of Basic Skills and teachers' ratings were the criterion measures. The MBSP ConApp had high reliability and criterion validity and growth for 6th and 7th grade participants. The MBSP-Comp was shown to have low levels of reliability and criterion validity in 7th grade participants. There was low test-retest reliability in the Estimation measure for 7th grade participants. The MBSP-ConApp and Complex Quantity Discrimination for participants in 7th grade, and Complex Quantity Discrimination for participants in 8th grade all had acceptable reliability and validity levels according to Foegen (2008).

Jiban and Deno (2007) examined if three 1-minute curriculum-based measures in mathematics (basic math fact sheets, and cloze math procedure) were technically adequate in predicting 84 third and fifth grade students' scores on a standardized state examination of mathematics. Specifically the researchers wanted to know how much unique variance each CBM measure contributed to the standardized tests scores, and also, were these CBM reliable and valid. Cloze math facts predicted state scores better than the basic math facts in 5th grade students. The Pearson product moment correlations between 3rd grade basic math facts scores (problems correct) and the state standardized test scores was .11. The same correlation for 5th grade was much higher, .55. The researchers found that adding students' maze scores to cloze math facts explained more variance in their state standardized test scores

As the aforementioned research indicates that CBM is a reliable and valid indicator of academic growth; however, there are some limitations that should be noted and addressed when designing research. First, the research supports longer assessment time in each assessment period. Thus, one minute is not necessarily adequate to assess

academic growth and apparent progress variance alone. Second, more than one data point is needed to establish stability over time. Multiple assessment periods can demonstrate level, trend, and variability in the data that could indicate support for a treatment particularly if the treatments are alternated in a counterbalanced order to rule out internal validity threats such as measurement error or treatment interaction.

Alternating treatment design

Alternating treatment design (ATD) involves a quick alternation of two or more interventions. Each treatment is made to be salient to the participant, that is to say, it is distinct. Each intervention is alternated and manipulated independently of each other (Cooper, Heron, & Heward, 2007). Alternating treatment design can involve alternating treatments across sessions each day, or during separate sessions during the same day or during a portion of the same session. To reduce variability of results, days of the week, the order in which the different treatments occur, and times of day are often counterbalanced.

Each data point in ATD predicts the future levels of the data in that intervention, it verifies the previous prediction of the data and it also replicates the preceding data points (Cooper, Heron, & Heward, 2007). In order to determine that the different treatments are causing the different levels of responding a visual inspection of the data is performed; the greater the distance between the data points and the horizontal axis the greater the effect of the treatments.

There are many variations of alternating treatment design, including single phase alternating treatments design without a no treatment control condition, single phase design in which no-treatment control condition and another condition are alternated, two

phase design in which a initial baseline phase is followed by a no treatment control condition and another condition are alternated, and a three phase design in which an initial baseline, a second phase change in which two or more conditions are alternated and a final phase where the best treatment is implemented (Cooper, Heron, & Heward, 2007). Experimental control is established by showing a different level of responding in the final treatment phase than was in the first treatment phase (Sindelar, Rosenburg, & Wilson, 1985).

Academic behaviors, such as algebra, are often complex but can be examined well using alternating treatment design (Sindelar, Rosenburg, & Wilson, 1985). Utilizing alternating treatment design has many benefits for comparing the effectiveness of interventions. One advantage is that it does not require treatment withdrawal to demonstrate the effectiveness of the intervention. Not having to withdrawal treatment is often more acceptable to teachers and participants (Ulman & Sulzer-Azaroff, 1975).

Alternating treatment design can produce results quickly and efficiently unlike reversal or multiple baseline designs. Sequence effects are minimized when utilizing ATD which improves internal validity. During ATD, the independent variables are alternated in a random way so as to assess carryover and sequence effects. ATD can also be utilized when the data is unstable. The effects of practice or maturation can be evenly spread across the conditions and therefore the results can be more confidently interpreted as an effect of the treatment (Cooper, Heron, & Heward, 2007).

Summary

Students who struggle in algebra do not acquire the necessary knowledge needed to perform high order mathematics. This limits the types of careers students can choose

and negatively impacts their ability to solve many every-day math problems. Eaton and Harding (1978) developed a learning hierarchy which examines the way in which students develop skills. The stages are: acquisition, fluency, generalization and adaptation. Drills, active repeated responding, performance feedback, and reinforcement of accurate responding can increase fluency, while repeated practice and problem solving can increase generalization and fluency. Previous research has demonstrated the effectiveness of using BEA to select interventions in mathematics and reading (Carson & Eckert, 2003). Performance feedback, passage previewing, contingent reinforcement, repeated practice have been shown to be effective in increasing fluency and accuracy in reading (Maccini et al, 2007). Peer tutoring, overcorrection, performance feedback, contingent reinforcement, cover-copy-compare, timed practiced have also been shown to effectively increase accurate and/or fluent mathematics responding (Coddington et al, 2007; Skinner et al, 1993; Sruthers et al., 1994; Poncy, Skinner, & Jaspers, 2006).

The reading and mathematics literature however have weaknesses due to lack of model adherence, how the interventions were selected, and the narrow scope of participants, and measurement and design flaws. Also, much of the research on mathematic interventions has been conducted at the elementary grade school level, this is intuitive because students who do not master basic math facts are unable to develop higher order math problem solving skills. However, there is still a need to examine effective math intervention strategies for students at the high school level, particularly in algebra, which is a foundational skill for math in the later grades.

Research questions

- 1) Which mathematics intervention strategies for linear equations are most effective for students at the frustrational level?
- 2) What strategies are most effective at the instructional level?
- 3) Which intervention (contingent reinforcement, repeated practice, mathematic problem previewing and immediate corrective feedback) is preferred by students?

Hypotheses

The current study hypothesized that students at the instructional level will see the greatest increase in performance when the repeated practice intervention is implemented. Students at the frustrational level will see the greatest increase in performance when immediate corrective feedback and/or repeated practice are implemented. It is predicted that students will prefer contingent reinforcement.

Method

Participants and Setting

The study received approval through a university Institutional Review Board (IRB) prior to the selection of participants or implementation of the procedures. In addition, each participant's parent(s) and or guardians gave informed consent. Assent also was obtained from each participant. The participants were selected from a midwestern high school Advanced Algebra classroom. Students were selected to participate based on their scores on a curriculum based measurement administered to their entire class. Three students were selected at the frustrational level meaning they scored between 40%-59% on accuracy on the curriculum based measurement of linear

equations. Four students were selected at the instructional level, meaning they scored between 60%-80% on accuracy. Students were excluded from participating in the study if they were receiving special education services.

Eight general education level students participated in the study. Due to scheduling and intermittent absences, one student did not complete the study. The average age of the participants was 15.9 years of age. Four girls and three boys completed the study. Madeline was a 15 year old, Asian female, who was in the 10th grade (frustrational level). Tony was a 17 year old, Hispanic male, who was in the 12th grade (frustrational level). Michael was a 16 year old, Caucasian male, who was in the 10th grade (frustrational level). Brianna was a 15 year old, Caucasian female, who was in the 10th grade (instructional level). Mayra was a 15 year old, Caucasian female, who was in the 10th grade, she self identified as being of Vietnamese descent (instructional level). Jeff was a 16 year old, white male, who was in the 10th grade, he self identified as being of Filipino descent (instructional level). Kayla was a 14 year old, Asian girl, who was in the 9th grade (instructional level).

Each participant worked with primary researcher in a medium sized room away from distractions. In the room, there was a desk and several chairs. The students were videotaped in the main office conference room, or in the psychology office, or in the hearing itinerant's office. Depending on the students' schedules they were progress monitored during different times of the day ranging from 7:45 a.m. to 1:57 p.m. The students were pulled from non-core subjects (e.g. P.E. art, study hall).

Materials

The linear equations were generated from mytestbook.com (Linear Equation Worksheet Generator, 2008). The worksheets contained two rows of five 2 variable linear equations problems for a total of 10 linear problems. The problems could be solved by elimination (multiplication/addition/subtraction/division) or by substitution. The worksheet contained the directions “please solve for x and y,” and the problems (See Appendix C for examples). The style and font were the same for each worksheet. Below each problem was space for the participant to solve the problem. In addition to the worksheets, a stopwatch, a clipboard, a video camera, and a treatment acceptability scale (CIRP) were used when working with the participants.

Dependent Variables

The dependent variables were digits correct per minute (DCPM), errors per minute (EPM), and rate of acquisition (ROA). Participants received math probes throughout baseline and all phases of the ATD. DCPM was the primary dependent variable used to make decisions about students at the instructional level and frustrational level. ROA was secondarily used to make decisions about all participants as well.

Fluency. DCPM was measured by summing the number of digits correct on each sheet, multiplying by 60 seconds and dividing by the number of seconds the student spent working on the problems. The number of seconds spent working on the problems was typically 300 seconds (5 minutes) unless the student completed the problems in less time. Each participant had five minutes to complete each worksheet. A digit was scored as correct when the correct numeral appeared next to the correct variable.

Errors per minute (EPM). EPM was measured by summing the number of errors on each sheet, multiplying that number by 60 seconds and dividing the number of seconds the student spent working on the problems, typically 300 seconds.

Rate of acquisition (ROA). Rate of acquisition was measured by the summation of the number of digits the participant answered correctly in one session to the number of digits they answered correctly in the next session, which yields a cumulative record. A digit was scored as correct when the correct numeral appeared next to correct variable. These data points were then graphed to examine the slope of the line.

Student acceptability. Students completed seven questions adapted from the Children's Intervention Rating Scale (CIRP) developed by Witt and Elliott (1985) to the students' acceptability of each of the interventions (Appendix H). The scale was on a 6 point Likert-scale with 1 being *I do not agree* and 3 being *I agree*. The CIRP has been shown to have acceptable levels of reliability and validity (e.g., a Cronbach alpha of .75, indicating internal consistency; Turco & Elliott) and validity (e.g., one-factor measure, demonstrating construct validity; Turco & Elliott).

Curriculum Based Assessment (CBA)

Before baseline, the researchers performed a CBA with the participant in order to ascertain the participant's instructional level. The probes contained different types of linear equation problems that were suggested by the teacher as areas of difficulty. Each participant had 5 minutes to complete the math worksheet. Then the researcher calculated the percentage correct (accuracy), errors per minute (EPM), and the digits correct per minute (DCPM). Participants who answered the problems between 40% -

59% accuracy were considered at the frustrational level. Participants who answered the problems with 60% - 80% accuracy were considered at the instructional level.

Procedures

The researcher worked with each participant for approximately 55 minutes. The time varied as a result of session type: establishing instructional level, conducting curriculum based assessment, assessing baseline or alternating treatments design.

Baseline

The researcher performed baseline assessments with each individual participant in a pull out setting. The participant was instructed to complete the math problems. Once baseline was stable or displayed a decreasing trend, then the independent variables were introduced.

If the data indicated stability then a criterion was used to assess the level of stability. In order for the data to be considered stable, 80-90% of the data points within baseline should fall within a 15% range of the phase mean. To calculate the stability range .15 was multiplied by the highest value in the phase (e.g., highest value = 20, $15\% \times 20 = 3$). The stability range was calculated by dividing the phase mean by 2. The result was adding or subtracted to the phase mean. These two numbers of the stability envelope (e.g. phase mean = 17.5, phase mean plus or minus the stability range $17.5 + 1.5 = 16$, and $17.5 - 1.5 = 19$, stability envelope 16-19). After the stability envelope was determined, the percentage of data points that fell within the stability envelope was calculated.

Independent Variables

The independent variables in the alternating treatment design (ATD) were chosen because of their support in various mathematic interventions (Daly, et al., 1997; Martens, Eckert, Bradley & Ardoyn 1999; Martens, Witt, et al., 1999, Carson & Eckert 2003, Coddington, et al., 2006). The intervention conditions were: (a) contingent reinforcement, (b) repeated practice, (c) mathematic problem previewing and (d) immediate corrective feedback. These components were counterbalanced across all the participants to control for order effects. All interventions were given during each session. The participants met with the researcher three to six times to establish baseline, then four to five times for the intervention conditions and once for best treatment implementation.

Contingent reinforcement (CR). Before the first CR session began, the researcher asked the participant to make a list of items he/she would work for in each session. The participant was asked to list items the participant would be willing to work for in the future session. Before the phase began, the experimenter asked each participant, "Name five things you would like to earn for improving your performance." The experimenter recorded five items that the participant named. Each item was written on half of an index card, folded over once and placed in a small bag. The participant was unable to view the names of items in the bag. At the beginning of all of the CR session, the experimenter said, "This bag has several pieces of paper with names of items you could earn. If your performance today is better than before you will be able to have this item." The participant completed one worksheet for five minutes. After the intervention session, the experimenter assessed the participant's progress. If the participant increased his or her performance by 15% or more, he/she selected a piece of paper out of the

container. The participant was then given the item he/she selected. Afterward, if he or she met the goal, the piece of paper was returned to the container.

Repeated practice (RP). Participants completed the same math worksheet three times. The participant was given 5 minutes to work each worksheet. This is an expansion of the procedures developed by Rashotte and Torgesen (1985). The experimenter gave standardized instructions to the participant to work on as many problems as possible within the time limit. On a fourth trial, the DCPM, EPM, and rate of acquisition were calculated. The first three probes were scored but not entered into the data set and therefore did not contribute to the DCPM, EPM, or ROA data.

Math worksheet problem previewing (PP). The researcher first read each problem aloud to the participant including the answer. The experimenter also previewed math worksheet describing the procedures involved in solving all linear equation problems (i.e. subtraction, substitution, addition, elimination, etc.) After describing the steps, the participant completed that one worksheet. This previewing procedure was an extension of the procedures developed by Daly and Martens (1994).

Immediate corrective feedback (ICF). The researcher provided immediate corrective feedback to the student for incorrect answers or a lack of response within 10 seconds. The experimenter pointed to the incorrect answer and repeated the problem aloud identifying the correct answer. (e.g. “solve for x, choose an original equation, substitute to value of x and simplify”) The participant was then instructed to work the next problem until all problems were complete, taking as much time as was needed. After all problems were complete, the participant was given another worksheet and he/she had five minutes to complete it without feedback from the researcher. This final

worksheet was scored for DCPM, EPM, and ROA, the first worksheet the participant received feedback on was not scored. The procedure was adapted from O'Shea, Munson, and O'Shea's (1984) error correction methodology.

Design.

After baseline was established the experimental conditions were implemented using an alternating treatment design (Higgins Hains, Baer, 1989; Sindelar, Rosenberg, & Wilson, 1985; Coddington et al., 2006). This design allowed a comparison of DCPM across four treatment conditions, which is an efficient way to assess effectiveness of the treatments (Sindelar et al., 1985; Rhymer, Dittmer, Skinner & Jackson, 2000). Then, the most effective intervention based on the visual analysis was implemented.

Data analysis. All dependent variables were graphed using an alternating treatment design. They were analyzed using a visual inspection focusing on the distance between the horizontal axis and the data in baseline and each condition of the ATD. Once visual separation was noted, then the best treatment was implemented with each student. ROA was also utilized to make best treatment decisions when divergence between data points was not clear. An analysis was also performed on instructional hierarchy (Haring & Eaton, 1978).

Inter-observer and inter-scorer agreement. Trained independent observers that were blind to the purpose of the study watched a video of each session. In order to ensure proper implementation of each condition a treatment integrity checklist was also utilized. Also, trained research assistants re-scored 33% of the math worksheets for DCPM and percent correct for inter-scorer agreement. The independent observers were

trained before the study to an agreement level of 85% before being able to participate in the study.

Inter-scorer agreement was calculated by adding the number of digit scoring agreements and number of digit scoring disagreements for all attempted items, dividing the number of agreements by the number of agreements plus disagreements, and multiplying the result by 100%. The mean inter-scorer agreement was 99.70% across all conditions and across all participants.

For Madeline the inter-scorer agreement results were as follows: across all conditions ($M = 100\%$, range 100% to 100%). For Michael the integrity results were as follows: across all conditions ($M = 99\%$, range 97% to 100%). For Tony the integrity results were as follows: across all conditions ($M = 99\%$, range 98% to 100%).

For Brianna the integrity results were as follows: across all conditions ($M = 100\%$, range 100% to 100%). For Mayra the integrity results were as follows: across all conditions ($M = 100\%$, range 99% to 100%). For Jeff the integrity results were as follows: across all conditions ($M = 100\%$, range 100% to 100%). For Kayla the integrity results were as follows: across all conditions ($M = 100\%$, range 100% to 100%).

Treatment integrity. Independent observers blind to the purpose of the study completed procedural checklists. The observers checked “Yes” or “No” to questions on the procedural checklist (See Appendix D, E, F, G). The percentage of steps correct was calculated by dividing the number of steps marked correct by the total number of steps. Treatment integrity was monitored for the following areas: correct presentation of materials, correct implementation of the instructions, and accurate timing.

The mean treatment integrity score across all conditions for each participant was 91% or greater. For Madeline the integrity results were as follows: ICF ($M = 100\%$, range 100% to 100%), PP ($M = 100\%$, range 100% to 100%), RP ($M = 100\%$, range 100% to 100%), CR ($M = 97\%$, range 82% to 100%).

For Michael the integrity results were as follows: ICF ($M = 100\%$, range 100% to 100%), PP ($M = 100\%$, range 100% to 100%), RP ($M = 100\%$, range 100% to 100%), CR ($M = 100\%$, range 100% to 100%).

For Tony the integrity results were as follows: ICF ($M = 100\%$, range 100% to 100%), PP ($M = 93\%$, range 80% to 100%), RP ($M = 89\%$, range 75% to 100%), CR ($M = 87\%$, range 75% to 100%).

For Brianna the integrity results were as follows: ICF ($M = 100\%$, range 100% to 100%), PP ($M = 100\%$, range 100% to 100%), RP ($M = 100\%$, range 100% to 100%), CR ($M = 100\%$, range 100% to 100%).

For Mayra the integrity results were as follows: ICF ($M = 97\%$, range 82% to 100%), PP ($M = 100\%$, range 100% to 100%), RP ($M = 94\%$, range 83% to 100%), CR ($M = 82\%$, range 82% to 82%).

For Jeff the integrity results were as follows: ICF ($M = 100\%$, range 100% to 100%), PP ($M = 100\%$, range 100% to 100%), RP ($M = 99\%$, range 92% to 100%), CR ($M = 100\%$, range 100% to 100%).

For Kayla the integrity results were as follows: ICF ($M = 100\%$, range 100% to 100%), PP ($M = 80\%$, range 80% to 80%), RP ($M = 100\%$, range 100% to 100%), CR ($M = 98\%$, range 82% to 100%).

Social validity. Treatment acceptability and treatment outcomes were determined by having students complete a brief questionnaire to record their thoughts and feelings about each intervention and its effectiveness. The students completed the CIRP (Witt & Elliot, 1985). The students completed the questionnaire after each intervention was completed (See Appendix). The CIRP was analyzed by calculating the mean rating of the items. The sum of all the items was divided by the total number of items.

Treatment acceptability outcomes were measured with five of the seven participants using the CIRP at the end of each session. Mean item scores for the students ranged from 2.4 to 3 (on a scale of 0 to 3). These high social validity scores suggest that the students viewed the interventions as overall fair, helpful, and likeable. The following scores represent the highest mean ratings for each participant: Michael had a mean rating of 2.8 on RP and PP, Tony had a mean rating of 3 on ICF, PP and CR, Mayra rated all interventions 3, and Brianna had a mean rating of 3 on RP. Jeff had a mean rating of 3 on ICF, RP, and PP. Kayla and Madeline were not administered the CIRP during all four interventions, and therefore their scores cannot be reported. This was due to implementer error.

Results

Descriptive Analysis of Instructional Level. During baseline, all frustrational level participants (Madeline, Michael, Tony) were achieving below a mean of 32 DCPM. All instructional level participants (Mayra, Brianna, Jeff, and Kayla) were achieving below a mean of 54 DCPM. After implementing best treatment, there were strong increases in DCPM for all participants. The instructional hierarchy research suggests that Madeline, Michael and Tony had moved from the acquisition level to the fluency level by

the last intervention session. Mayra, Brianna, and Jeff had moved from the fluency level to the mastery level by the last intervention session. Kayla's performance for the majority of the sessions after baseline fell within the mastery level and during CR in one session had moved into the adaptation level.

Madeline. Table 1 and Figure 1 display the digits correct per minute for Madeline across all conditions. For Madeline, increases in the number of digits correct per minute were observed following the presentation of all interventions. During ATD, Madeline achieved the highest mean (62.60 DCPM) under RP conditions. After baseline (range, 17.2 to 48.2) strong improvements in the digits correct per minute were displayed for Madeline after the implementation of RP (range, 44 to 79.60), ICF (range, 45.2 to 60), and CR (range, 43.2 to 56.40). There was a moderate improvement in her digits correct per minute score after the implementation of PP (range, 21.6 to 66.6).

A visual analysis was performed on the DCPM and ROA data to determine best treatment. The distance between the data points and the x axis was examined. RP had the highest DCPM score in three out of the four sessions for Madeline. Also there was divergence between RP and all other interventions when examining ROA. The following data were the slopes for best treatment RP: DCPM slope = 4.62, EPM slope = .08, ROA slope = 61.88.

Table 2 and Figure 2 display the errors per minute for Madeline across all conditions. During ATD, Madeline obtained the lowest mean errors per minute score (.24) under RP conditions. After baseline (range, 0 to 9) there was a decrease in the number of errors per minute Madeline made. The strongest decrease occurred after the implementation of ICF (range, 0 to .8) and RP (range, 0 to .8). There was a moderate

improvement in her EPM score after the implementation of PP (range, 0 to 1.8).

Madeline's mean baseline EPM (3.40) was higher than her performance during all other interventions).

Table 3 and Figure 3 display the rate of acquisition for Madeline across all conditions. During ATD, Madeline obtained the highest mean rate of acquisition under RP (178.56). She also had strong increases in rate of acquisition during ICF ($M = 128.80$). PP had the lowest mean rate of acquisition (108.90).

Michael. Table 4 and Figure 4 display the digits correct per minute for Michael across all conditions. For Michael, increases in the number of digits correct per minute were observed following the presentation of all interventions. During ATD, Michael achieved the highest mean (64.66 DCPM) under RP conditions. After baseline (range, 6.6 to 26.4) strong improvements in the digits correct per minute were displayed for Michael after the implementation of RP (range, 40 to 91.53), ICF (range, 32.60 to 51.60), and CR (range, 28.2 to 49.6). There was a moderate improvement in his digits correct per minute score after the implementation of PP (range, 28.6 to 37.6). There was no overlap between any of the intervention data points and the baseline data points.

A visual analysis was performed on the DCPM and ROA data to determine best treatment. The distance between the data points and the x axis was examined. RP had the highest DCPM score in three out of the four sessions for Michael. Also there was clear divergence between RP and all other interventions when examining ROA. The following data were the slopes for best treatment RP: DCPM slope = 9.33, EPM slope = -.16, ROA slope = 65.73.

Table 5 and Figure 5 display the errors per minute for Michael across all conditions. During ATD, Michael obtained the lowest mean errors per minute score (.35) under ICF conditions. After baseline (range, .4 to 3.6) there was a decrease in the number of errors per minute Michael made. The strongest decrease occurred after the implementation of ICF (range, 0 to 1.4) and RP (range, 0 to 1).

Table 6 and Figure 6 display the rate of acquisition for Michael across all conditions. During ATD, Michael obtained the highest mean rate of acquisition under RP (175.35). He also had strong increases in rate of acquisition during ICF ($M = 101.60$). PP had the lowest mean rate of acquisition (84.30).

Tony. Table 7 and Figure 7 display the digits correct per minute for Tony across all conditions. For Tony, increases in the number of digits correct per minute were observed following the presentation of all interventions. During ATD, Tony achieved the highest mean (47.68 DCPM) under RP conditions. After baseline (range, 7 to 20.80) strong improvements in the digits correct per minute were displayed for Tony after the implementation of RP (range, 33.40 to 73), ICF (range, 33 to 35.20), and passage previewing (range, 24.60 to 46.40). There was a slight improvement in his digits correct per minute score after the implementation of CR (range, 5.6 to 45.40).

A visual analysis was performed on the DCPM and ROA data to determine best treatment. The distance between the data points and the x axis was examined. RP had the highest DCPM score in three out of the four sessions for Tony. The following data were the slopes for best treatment RP: DCPM slope = 9.54, EPM slope = -.24, ROA slope = 50.14.

Table 8 and Figure 8 display the errors per minute for Tony across all conditions. During ATD, Tony obtained the lowest mean errors per minute score (.40) under PP conditions. After baseline (range, .4 to 4.2) there was a lower level in the number of errors per minute Tony made during the ICF, PP, and RP conditions. During the CR condition there was an increase in level and then a large decrease. The strongest decrease occurred after the implementation of PP (range, 0 to 1.4) and ICF (range, 0.4 to .8). Tony's mean baseline EPM (2.90) was higher than his performance during all other interventions).

Table 9 and Figure 9 display the rate of acquisition for Tony across all conditions. During ATD, Tony obtained the highest mean rate of acquisition under RP (123.96). He also had strong increases in rate of acquisition during PP ($M = 84.30$). CR had the lowest mean rate of acquisition (39.40).

Brianna. Table 10 and Figure 10 display the digits correct per minute for Brianna across all conditions. For Brianna, increases in the number of digits correct per minute were observed following the presentation of all interventions. During ATD, Brianna achieved the highest mean (66.59 DCPM) under RP conditions. After baseline (range, 25.40 to 41.20) strong improvements in the digits correct per minute were displayed for Brianna after the implementation of RP (range, 42.80 to 106.15), ICF (range, 41.20 to 71.60), and CR (range, 34.60 to 76.60). There was a moderate improvement in her digits correct per minute score after the implementation of PP (range, 25.8 to 63.6). There was a steep increase for RP, PP, and CR, while ICF displayed a less improvement.

A visual analysis was performed on the DCPM and ROA data to determine best treatment. The distance between the data points and the x axis was examined. RP had

the highest DCPM score in three out of the five sessions for Brianna. The following data were the slopes for best treatment RP: DCPM slope = 10.56, EPM slope = -.42, ROA slope = 62.52. Brianna mean best treatment slope DCPM 10.56, EPM -.42, ROA 62.52.

Table 11 and Figure 11 display the errors per minute for Brianna across all conditions. During ATD, Brianna obtained the lowest mean errors per minute score (.77) under RP conditions. After baseline (range, 0.60 to 8) there was a decrease in the number of errors per minute Brianna made. The strongest decrease occurred after the implementation of RP (range, 0 to 2.2) and PP (range, 0.2 to 2). There was a moderate improvement in her EPM score after the implementation of ICF (range, 0 to 3.6). Brianna's mean baseline EPM (3.10) was higher than her performance during all other interventions).

Table 12 and Figure 12 display the rate of acquisition for Brianna across all conditions. During ATD, Brianna obtained the highest mean rate of acquisition under RP (182.49). She also had strong increases in rate of acquisition during ICF ($M = 156$). PP had the lowest mean rate of acquisition (112.76).

Mayra. Table 13 and Figure 13 display the digits correct per minute for Mayra across all conditions. For Mayra, increases in the number of digits correct per minute were observed following the presentation of all interventions. During ATD, Mayra achieved the highest mean (66.54 DCPM) under RP conditions. After baseline (range, 25 to 49.60) strong improvements in the digits correct per minute were displayed for Mayra after the implementation of RP (range, 51 to 87.12), ICF (range, 40.80 to 58.40), and CR

(range, 40.4 to 75). There was a moderate improvement in her digits correct per minute score after the implementation of PP (range, 36.8 to 53.6).

A visual analysis was performed on the DCPM and ROA data to determine best treatment. The distance between the data points and the x axis was examined. There was clear divergence between RP and the other intervention data points when examining Mayra's ROA. The following data were the slopes for best treatment RP: DCPM slope = 6.04, EPM slope = .02, ROA slope = 66.32.

Table 14 and Figure 14 display the errors per minute for Mayra across all conditions. During ATD, Mayra obtained the lowest mean errors per minute score (.05) under CR conditions. After baseline (range, 0 to 2.2) there was a stable number of errors per minute Mayra made during all conditions except for ICF, which had a small increase. During ICF, RP and PP the mean EPM was below .80. Mayra's mean baseline EPM (3.40) was higher than her performance during all other interventions).

Table 15 and Figure 15 display the rate of acquisition for Myra across all conditions. During ATD, Mayra obtained the highest mean rate of acquisition under RP (187.54). She also had moderate increases in rate of acquisition during CR ($M = 126.85$) and ICF ($M = 124.40$). PP had the lowest mean rate of acquisition (109.60).

Jeff. Table 16 and Figure 16 display the digits correct per minute for Jeff across all conditions. For Jeff, increases in the mean number of digits correct per minute were observed following the presentation of all interventions except ICF. During ATD, Jeff achieved the highest mean (71.96 DCPM) under RP conditions. After baseline (range, 23.40 to 51.60) strong improvements in the digits correct per minute were displayed for Jeff after the implementation of RP (range, 40.4 to 96.70), passage previewing (range,

31.40 to 71.60), and CR (range, 37.60 to 61.40). There was a moderate improvement in his digits correct per minute score after the implementation of ICF (range, 39.20 to 59.60).

A visual analysis was performed on the DCPM and ROA data to determine best treatment. The distance between the data points and the x axis was examined. There was divergence between the data points by the fourth session; RP was over 16 DCPM higher than any intervention. When examining Jeff's ROA, there was clear divergence between RP and the other data points across sessions. The following data were the slopes for best treatment RP: DCPM slope = 10.11, EPM slope = 0, ROA slope = 72.60.

Table 17 and Figure 17 display the errors per minute for Jeff across all conditions. During ATD, Jeff obtained the lowest mean errors per minute score (.08) under RP conditions. After baseline (range, 0 to 2.4) there was a decrease in the number of errors per minute Jeff made for all interventions except CR, in which there was a small increase. The strongest decrease occurred after the implementation of RP (range, 0 to .4) and ICF (range, 0 to 1.2). Jeff's mean baseline EPM (.70) was higher than his performance during all other interventions except CR ($M = .95$).

Table 18 and Figure 18 display the rate of acquisition for Jeff across all conditions. During ATD, Jeff obtained the highest mean rate of acquisition under RP (195.65). He also had moderate increases in rate of acquisition during CR ($M = 123.25$) and PP ($M = 119.30$). ICF had the lowest mean rate of acquisition (110.65).

Kayla. Table 19 and Figure 19 display the digits correct per minute for Kayla across all conditions. For Kayla, increases in the number of digits correct per minute were observed following the presentation of all interventions. During ATD, Kayla

achieved the highest mean (79.58 DCPM) under CR conditions. After baseline (range, 48.2 to 57) strong improvements in the digits correct per minute were displayed for Kayla after the implementation of RP (range, 75.2 to 87.65) and CR (range, 56 to 110.75).

There was a moderate improvement in her digits correct per minute score after the implementation of PP (range, 56.40 to 78.73) and ICF (range, 61.60 to 70). Kayla's mean baseline DCPM (54.10) was lower than her performance during all other interventions.

A visual analysis was performed on the DCPM and ROA data to determine best treatment. The distance between the data points and the x axis was examined. There was clear divergence between the data points by the fourth session, CR was over 33 DCPM higher than any intervention. The following data were the slopes for best treatment CR: DCPM slope = 9.20, EPM slope = -.17, ROA slope = 86.55. Kayla best treatment slope DCPM 9.2, EPM -.17, ROA 86.55.

Table 20 and Figure 20 display the errors per minute for Kayla across all conditions. The strongest decrease occurred after the implementation of RP (range, 0 to 1.6). Kayla's mean baseline EPM (.70) was higher than her performance during RP. However, the mean number of EPM was higher for ICF, CR and PP than it was during baseline.

Table 21 and Figure 21 display the rate of acquisition for Kayla across all conditions. During ATD, Kayla obtained the highest mean rate of acquisition under CR (220.35). She also had strong increases in rate of acquisition during RP ($M = 201.84$). ICF had the lowest mean rate of acquisition (160.70).

Summary of results

All instructional level participants and frustrational level participants achieved the highest mean DCPM score for the RP conditions. Three out of the four instructional level students (Brianna, Kayla, and Jeff), and one of the frustrational level students (Madeline) achieved the lowest mean EPM score during the RP conditions. For Tony the mean EPM scoring for the PP conditions was his lowest, while ICF had the lowest mean EPM score for Michael. The mean DCPM across conditions for frustrational level participants was 45.47, while the mean DCPM across conditions for instructional level participants was 60.01. The mean EPM between the groups was more similar. The mean EPM across conditions for frustrational level participants was .81, while the mean EPM across conditions for instructional level participants was .80.

A visual analysis was performed on the data focusing on separation between the data points. Five of the seven participants had separation by the fourth data point. One participant, Brianna, had clear separation after five data points. Madeline's best treatment intervention was chosen by calculating the percentage of times each intervention had the maximum DCPM for each session. The best treatment for all three of the participants at frustrational level, Madeline, Michael, and Tony, was RP. The best treatment for three of the four students (Jeff, Brianna, and Mayra) at instructional level (fluency) was also RP. The best treatment for Kayla, who was at the instructional level, was CR.

The most frequently made error by the participants was an addition error when combining like variables with different signs. This error occurred 17 times. The second most common error made was a multiplication error when distributing a number to a

quantity in parenthesis. This type of error occurred 7 times. The third most commonly made error was a multiplication error involving basic multiplication facts. This error occurred 6 times.

Discussion

One purpose of the current study was to evaluate the effectiveness of math interventions for students with skills at different levels in the instructional hierarchy. All three students at the frustrational level and three out of four students at the instructional level showed the most improvement when the RP intervention was implemented. These findings support our hypothesis that students at the instructional and frustrational levels in the instructional hierarchy would show the most improvement from RP interventions. These results are supported by previous studies regarding repeated practice. Ardoin and Daly, (2007) suggest that fluency can be increased with multiple opportunities for correct responding. Daly, et al., (1997) and Maccini et al., (2007) also support the use of repeated independent practice to improve scores.

In addition to providing multiple opportunities to respond, RP may be negatively reinforcing to students responding behavior. In the current study, the same ten linear equation problems were completed four times by participants during the RP conditions. As each sheet of problems is completed the participants may have been motivated to respond as quickly as they could to finish the next worksheet in order for the task to be completed. In fact, during the best treatment session and/or the fourth session, all participants completed the RP fourth presentation of problems in less than five minutes. This repeated practice may have encouraged students to beat their previous scores. This idea has been found to be effective in previous studies as well (Rhymer et al., 2000). RP

may have also provided participants another opportunity to practice what they have learned in other conditions such as PP and ICF.

Kayla, who began the study at the instructional level, showed the most improvement during the CR intervention condition. This student may have progressed rapidly through the instructional hierarchy during the study and moved from the instructional level to the mastery level. Because she could solve the problems rapidly and accurately, the added motivational component in CR may have provided the motivation needed to substantially increase her digits correct per minute, suggesting that Kayla had a performance deficit. This finding supports the research by Noell, et al., (2004) which states that performance deficits can be remediated with contingent rewards. Kayla was the only participant whose EPM increased as the study progressed. This could be due to her increase in DCPM. Perhaps she solved problems more quickly at the expense of accuracy.

Although ICF was not selected as the best treatment for any of the students at the frustrational level, it did increase their performance over baseline. For Madeline and Michael, the mean score for ICF was second only to RP, which was their best treatment. The other frustrational level participant, Tony, began the sessions with the lowest mean digits correct per minute. He seemed to be anxious during CR conditions as well the ICF conditions. Perhaps the added attention to his errors and performance level was somewhat punishing. Mayra and Jeff both had sessions during ICF in which they made no errors and therefore did not receive ICF. This condition serves as a control for them since no intervention was implemented. ICF did result in a reduction of errors primarily in students at the frustrational level.

The current study adds to the literature in several ways. Primarily, little research has been conducted on the effectiveness of math interventions with high school students. Also, rate of acquisitions has typically not been measured in mathematics intervention studies. This study uses an extended Brief Experimental Analysis procedure. Previous studies have only performed the interventions one time; error alone could account of any results the interventions achieved.

All participants except Kayla had a lower mean EPM during the PP condition than during baseline. However, for many participants passage previewing had the lowest mean score for digits correct per minute. Perhaps the repetition of the multiple steps needed to solve all 10 problems on the worksheet was too lengthy for participants. Future research should examine how the number of problems or steps explained affects the performance during passage previewing. Some participants may only require two to three problems previewed before they understand how to solve the remaining items.

For four participants rated ICF, RP, and PP the highest in terms of fairness, effectiveness and likeability. These results do not support our hypothesis that students would most prefer CR. Perhaps during these other interventions, students were more successful or could more easily see their progress (i.e. completing more problems during each phase of RP, fewer corrections during ICF) than in CR.

Limitations. There are several limitations that should be noted. Certain interventions may have worked better as the students moved into their instructional range. As previously mentioned, some students may have changed instructional levels as the study progressed. This may be due to learning. Perhaps learning is continually taking place for each intervention and therefore it may not be possible to obtain clear

divergence in the data after each session. The study's design has limitations as well. As mentioned previously some participants during ICF made no errors and therefore did not receive any intervention during that condition. For two participants that condition was a control. The ATD is designed to assess for carryover effects and this may be what was seen in the results that the students learned in the previous sessions, which was brought over to the new condition.

Also, in the CR condition, the reinforcers the participant requested may or may not have been a true reinforcer for that student. Some students completed the problems in a different order each time during RP, which may have affected the successfulness of that intervention. This study took places over several weeks. Between the second and third session and the third and fourth session the students were on thanksgiving break (5 schools days off) and winter break (10 school days off) respectively. This could have had an impact on their scores after returning from break. Another limitation of the study is the small sample size. These results cannot be generalized outside of this school setting or outside of this population of students.

Future research should examine the effectiveness of interventions when solving linear equations with different methods such as with matrices and Cramer's rule, or graphing (slope intercept). In order to increase the validity of this study it should be replicated multiple times with a variety of students including those receiving special education services. Future research could also determine if different math interventions work best for different types of linear equations (all substitution/elimination problems vs. substitution and elimination problems mixed). These data suggests that RP can

significantly improve mathematics performance for students at both the instructional level and frustrational level.

References

- Allsopp, D. (1997). Using class wide peer tutoring to teach beginning algebra problem-solving skills in heterogeneous classrooms. *Remedial and Special Education, 18*, 367-379.
- Ardoin, S., & Daly, E. (2007). Introduction to the special series: close encounters of the instructional kind—How the instructional hierarchy is shaping instructional research 30 years later. *Journal of Behavioral Education, 16*, 1-6.
- Bragg, S., Charles, R., & Kennedy, D. (2006). *Prentice Hall Mathematics: Algebra 2*. Toronto: Pearson Prentice Hall.
- Burger, E., Chard, D., Hall, E., Kennedy, P., Leinwand, S., Renfro, F., et al. (2007). *Algebra 1* (Student Ed.). Austin: Holt Rinehart & Winston.
- Burns, M., & Wagner, D. (2008). Determining an effective intervention within a brief experimental analysis for reading: A meta-analytic review. *School Psychology Review, 37*, 126-136.
- Busch, T., & Reschly, A. (2007). Progress monitoring in reading. Using curriculum based measurement in a response to intervention model. *Assessment for Effective Intervention, 32*, 223-230.
- Calhoon, M. (2008). Curriculum-Based measurement for mathematics at the high school level: What we do not know...what we need to know. *Assessment for Effective Intervention, 33*, 234-239.
- Calhoon, M., & Fuchs, L. (2003). The effects of peer-assisted learning strategies and curriculum-based measurement on the mathematics performance of secondary students with disabilities. *Remedial and Special Education, 24*, 235-244.

- Carson, P., & Eckert, T. (2003). An experimental analysis of mathematics instructional components: Examining the effects of student-selected versus empirically-selected interventions. *Journal of Behavioral Education, 12*, 35-54.
- Chambers, D. (1994). The right algebra for all. *Educational Leadership, 51*, 85.
- Christ, T., Johnson-Gros, K., & Hintze, J. (2005). An examination of alternate assessment durations when assessing multiple skill computational fluency: The generalizability and dependability of curriculum-based outcomes within the context of educational decisions. *Psychology in the Schools, 42*, 615-622.
- Christ, T., & Silberglitt, B. (2007). Estimates of the standard error of measurement for curriculum based measures of oral reading fluency. *School Psychology Review, 36*, 130-146.
- Codding, R., Eckert, T., Fanning, E., Shiyko, M., & Solomon, E. (2007). Comparing mathematics interventions: The effects of cover-copy-compare along and combined with performance feedback on digits correct and incorrect. *Journal of Behavioral Education, 16*, 125-141.
- Cooper, J. O., Heron, T. E., & Heward, W. L. (2007). *Applied Behavior Analysis* (2 ed.). Alexandria, VA: Prentice Hall.
- Daly, E., & Martens, B. (1994). A comparison of three interventions for increasing oral reading performance: Application of the instructional hierarchy. *Journal of Applied Behavior Analysis, 27*, 459-469.
- Daly, E., Witt, J., Martens, B., & Dool, E. (1997). A model for conducting a functional analysis of academic performance problems. *School Psychology Review, 26*, 554-574.
- Eckert, T., Ardoin, S., Daisey, D., & Scarola, M. (2000). Empirically evaluating the

- effectiveness of reading interventions: The use of brief experimental analysis and single case designs. *Psychology in the Schools*, 37, 463-473.
- Eckert, T., Ardoin, S., Daly, E., & Martens, B. (2002). Improving oral reading fluency: A brief experimental analysis of combining an antecedent intervention with consequences. *Journal of Applied Behavior Analysis*, 35, 271-281.
- Foegen, A. (2008). Progress monitoring in middle school mathematics: Options and issues. *Remedial and Special Education*, 29, 195-207.
- Fore, C., Boon, R., & Martin, C. (2007). Concurrent and predictive criterion related validity of curriculum-based measurement for students with emotional and behavioral disorders. *International Journal of Special Education*, 22, 24-32.
- Hains, A., & Baer, D. (1989). Interaction effects in multielement designs: Inevitable, desirable, and ignorable. *Journal of Applied Behavior Analysis*, 22, 57-69.
- Haring, N. G., & Eaton, M. D. (1978). Systematic instructional technology: An instructional hierarchy. In N. G. Haring, T. C. Lovitt, M. D. Eaton, & C. L. Hansen (Eds.), *The fourth R: Research in the classroom* (pp. 23-40). Columbus, OH: Merrill.
- Hintze, J., & Conte, K. (1997). Oral reading fluency and authentic reading material: Criterion validity of the technical features of CBM survey level assessment. *School Psychology Review*, 26, 535-53.
- Hintze, J., Owen, St., Shapiro, E., Daly, E. (2000). Generalizability of oral reading fluency measures: Application of G theory to curriculum-based measurement. *School Psychology Quarterly*, 15, 52-68.
- Jiban, C., & Deno, S. (2007). Using math and reading curriculum-based measurements to predict state mathematics test performance: Are simple one-minute measures

- technically adequate? *Assessment for Effective Intervention*, 32, 78-89.
- Kuhn, L., Watson, L., Ota, M., Cole, M., & Johnson-Gros, K. (2009). Effects of a brief experimental analysis and a reading intervention on multiple dependent variables. *Journal of Evidence-Based Practices for Schools*, 10, 23-47.
- Maccini, P., Mulcahy, C., & Wilson, M. (2007). A follow-up of mathematics interventions for secondary students with learning disabilities. *Learning Disabilities Research & Practice*, 22, 58-74.
- Marston, D. (1989). A curriculum-based measurement approach to assessing academic performance: What is it and why do it. In M.R. Shinn (Ed.) *Curriculum-based measurement: Assessing special children* (pp. 18-78). NY: Guilford Press.
- Martens, B., & Eckert, T. (2007). The instructional hierarchy as a model of stimulus control over student and teacher behavior: We're close but are we close enough? *Journal of Behavioral Education*, 16, 83-91.
- Martens, B., Eckert, T., Bradley, T., & Ardoin, S. (1999). Identifying effective treatments from a brief experimental analysis: Using single-case design elements to aid decision making. *School Psychology Quarterly*, 14, 163-181.
- Martens, B., Witt, J., Daly, E., & Vollmer, T. (1999). Behavior analysis: Theory and practice in educational settings. In C.R. Reynolds & T.B. Gutkin (Eds.), *Handbook of school psychology* (3rd ed., pp. 638-663). NY: John Wiley & Sons.
- Martens, B., Witt, J., Elliott, S., & Darveaux, D. (1985). Teacher judgments concerning the acceptability of school-based interventions. *Professional Psychology: Research and Practice*, 16, 191-198.
- Montague, M., Penfield, R., Enders, C., & Huang, J. (2009). Curriculum-based

- measurement of math problem solving: A methodology and rationale for establishing equivalence of scores. *Journal of School Psychology*, 48, 39-52
- O'Shea, L., Munson, S., & O'Shea, D. (1984). Error correction in oral reading: Evaluating the effectiveness of three procedures. *Education and Treatment of Children*, 7, 203-214.
- Poncy, B., Skinner, C., & Axtell, P. (2005). An Investigation of the Reliability and Standard Error of Measurement of Words Read Correctly Per Minute Using Curriculum-Based Measurement. *Journal of Psychoeducational Assessment*, 23, 326-338.
- Poncy, B., Skinner, C., & Jaspers, K. (2006). Evaluating and comparing interventions designed to enhance math fact accuracy and fluency: cover, copy, and compare versus taped problems. *Journal of Behavioral Education*, 16, 27-37.
- Poncy, B., Skinner, C., & O'Mara, T. (2006). Detect, practice, and repair: The effects of a class wide intervention on elementary students' math-fact fluency. *Journal of Evidence-Based Practices for Schools*, 7, 47-68.
- Rhymer, K., Skinner, C., Jackson, S., McNeill, S., Smith, T., & Jackson, B. (2002). The 1-minute explicit timing intervention: The influence of mathematics problem difficulty. *Education and Treatment of Children*, 29, 305-311.
- Rhymer, K., Dittmer, K., Skinner, C., & Jackson, B. (2000). Effectiveness of a multi-component treatment for improving mathematics fluency. *School Psychology Quarterly*, 15, 40-51.
- Rashotte, C., & Torgesen, J. (1985). Repeated reading and reading fluency in learning disabled children. *Reading Research Quarterly*, 20, 180-188.

- Shin, J., Deno, S., & Epsin, C. (2000). Technical adequacy of the maze task for curriculum-based measurement of reading growth. *The Journal of Special Education, 34*, 164-172.
- Sindelar, P. T., Rosenberg, M. S., & Wilson, R. J. (1985). An adapted alternating treatments design for instructional research. *Education and Treatment of Children, 8*, 67-76.
- Skinner, C., Bamberg, H., Smith, E., & Powell, S. (1993). Cognitive cover, copy, and compare: Subvocal responding to increase rates of accurate division responding. *Remedial and Special Education, 14*, 49-56.
- Skinner, C., Turco, T., Beatty, K., & Rasavage, C. (1989). Cover, copy, and compare: An intervention for increasing multiplication performance. *School Psychology Review, 18*, 212, 220.
- Linear Equation Worksheet Generator. (2008). *mytestbook.com*. Retrieved March 31, 2010, from www.mytestbook.com
- Struthers, J., Bartlamay, H., Bell, S., & McLaughlin, T. (1994). An analysis of the add-a-word spelling program and public posting across three categories of children with special needs. *Reading Improvement, 31*, 28-36.
- Usiskin, Z. (1995). Why is algebra important to learn? *American Educator, 19*, 30-37.
- Witt, J., & Elliot, S. (1985). Acceptability of classroom intervention strategies. In T.R. Kratochwill (Ed.) *Advances in school psychology* (Vol. 4, pp. 51-288). NJ: Erlbaum.
- Wolf, M. (1978). Social validity: The case for subjective measurement or how applied behavior analysis is finding its heart. *Journal of Applied Behavior Analysis, 11*, 203-214.

Woodward, J. (2006). Developing automaticity in multiplication facts: Integrating strategy instruction with timed practice drills. *Learning Disability Quarterly*, 29, 269-289.

Table 1. Summary of means, medians, ranges, and slope of digits correct per minute for Madeline across conditions

Condition	Digits Correct Per Minute			
	Mean	Median	Range	Slope
Baseline	31.20	28.20	31.00	
RP	58.35	60.70	24.00	
ICF	52.40	52.20	14.80	
CR	51.00	52.20	13.20	
PP	50.35	56.60	45.00	
Best Treatment RP	62.60	61.80	35.60	4.62

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 2. Summary of means, medians, ranges, and slope of errors per minute for Madeline (frustrational level) across conditions

Condition	Errors Per Minute			
	Mean	Median	Range	Slope
Baseline	3.40	1.20	9.00	
RP	0.25	0.10	0.80	
ICF	0.25	0.10	0.80	
CR	1.40	0.00	5.60	
PP	0.45	0.00	1.80	
Best Treatment RP	0.24	0.20	0.80	0.08

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 3. Summary of means, medians, ranges, and slope for rate of acquisition for Madeline (frustrational level) across conditions

Condition	Rate of Acquisition			
	Mean	Median	Range	Slope
RP	144.95	143.40	173.80	
ICF	128.80	127.00	158.00	
CR	125.10	126.60	160.80	
PP	108.90	106.30	179.80	
Best Treatment RP	178.56	165.40	253.40	61.88

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 4. Summary of means, medians, ranges, and slope of digits correct per minute for Michael (frustrational level) across conditions

Condition	Digits Correct Per Minute			
	Mean	Median	Range	Slope
Baseline	18.04	19.00	19.80	
RP	57.95	57.00	37.80	
ICF	41.15	40.20	19.00	
CR	40.75	42.60	21.40	
PP	34.70	36.39	9.00	
Best Treatment RP	64.66	60.40	51.53	9.33

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 5. Summary of means, medians, ranges, and slope of errors per minute for Michael (frustrational level) across conditions

Condition	Errors Per Minute			
	Mean	Median	Range	Slope
Baseline	1.92	2.00	3.20	
RP	0.50	0.50	1.00	
ICF	0.35	0.00	1.40	
CR	1.15	1.10	3.40	
PP	1.55	1.70	1.60	
Best Treatment RP	0.40	0.40	1.00	-0.16

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 6. Summary of means, medians, ranges, and slope of rate of acquisition for Michael (frustrational level) across conditions

Condition	Rate of Acquisition			
	Mean	Median	Range	Slope
RP	138.35	143.40	178.20	
ICF	101.60	127.00	132.00	
CR	98.20	126.60	134.80	
PP	84.30	84.90	110.20	
Best Treatment RP	175.35	165.40	269.73	65.73

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 7. Summary of means, medians, ranges, and slope of digits correct per minute for Tony (frustrational level) across conditions

Condition	Digits Correct Per Minute			
	Mean	Median	Range	Slope
Baseline	13.90	13.80	13.80	
RP	41.35	37.60	23.40	
ICF	33.45	33.50	3.60	
CR	22.15	18.80	39.80	
PP	35.05	34.60	21.80	
Best Treatment RP	47.68	40.60	39.60	9.54

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 8. Summary of means, medians, ranges, and slope of errors per minute for Tony (frustrational level) across conditions

Condition	Errors Per Minute			
	Mean	Median	Range	Slope
Baseline	2.90	4.20	3.80	
RP	0.75	0.70	1.20	
ICF	0.60	0.60	0.40	
CR *	2.60	1.30	7.40	
PP	0.40	0.10	1.40	
Best Treatment RP	0.60	0.60	1.40	-0.24

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 9. Summary of means, medians, ranges, and slope of rate of acquisition for Tony (frustrational level) across conditions

Condition	Rate of Acquisition			
	Mean	Median	Range	Slope
RP	95.35	91.30	132.00	
ICF	83.25	83.80	102.20	
CR	39.40	31.70	83.00	
PP	84.30	86.20	115.60	
Best Treatment RP	123.96	108.60	205.00	50.14

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 10. Summary of means, medians, ranges, and slope of digits correct per minute for Brianna (instructional level) across conditions

Condition	Digits Correct Per Minute			
	Mean	Median	Range	Slope
Baseline	31.90	30.90	15.80	
RP	53.55	47.40	37.40	
ICF	53.52	47.40	30.40	
CR	55.68	61.80	42.00	
PP	43.96	49.00	37.80	
Best Treatment RP	66.59	63.30	63.35	10.56

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 11. Summary of means, medians, ranges, and slope of errors per minute for Brianna (instructional level) across conditions

Condition	Errors Per Minute			
	Mean	Median	Range	Slope
Baseline	3.10	2.60	7.60	
RP	0.92	0.60	2.20	
ICF	1.20	0.00	3.60	
CR	1.92	1.40	6.40	
PP	0.92	0.80	1.80	
Best Treatment RP	0.77	0.50	2.20	-0.42

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 12. Summary of means, medians, ranges, and slope of rate of acquisition for Brianna (instructional level) across conditions

Condition	Rate of Acquisition			
	Mean	Median	Range	Slope
RP	154.92	134.00	250.60	
ICF	156.00	149.00	226.40	
CR	145.60	133.40	243.80	
PP	112.76	107.20	194.00	
Best Treatment RP	182.49	174.10	277.55	62.52

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 13. Summary of means, medians, ranges, and slope of digits correct per minute for Mayra (instructional level) across conditions

Condition	Digits Correct Per Minute			
	Mean	Median	Range	Slope
Baseline	38.60	39.40	24.60	
RP	61.40	63.10	17.40	
ICF	50.25	50.90	17.60	
CR	56.10	54.50	34.60	
PP	46.55	47.90	16.80	
Best Treatment RP	66.54	65.60	36.12	6.04

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 14. Summary of means, medians, ranges, and slope of errors per minute for Mayra (instructional level) across conditions

Condition	Errors Per Minute			
	Mean	Median	Range	Slope
Baseline	0.60	0.00	2.20	
RP	0.10	0.10	0.20	
ICF	0.70	0.30	2.20	
CR	0.05	0.00	0.20	
PP	0.35	0.40	0.20	
Best Treatment RP	0.12	0.20	0.20	0.02

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 15. Summary of means, medians, ranges, and slope of rate of acquisition for Mayra (instructional level) across conditions

Condition	Rate of Acquisition			
	Mean	Median	Range	Slope
RP	151.25	146.90	180.00	
ICF	124.40	122.20	148.80	
CR	126.85	118.20	177.80	
PP	109.60	107.70	149.40	
Best Treatment RP	187.54	177.20	267.12	66.32

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 16. Summary of means, medians, ranges, and slope of digits correct per minute for Jeff (instructional level) across conditions

Condition	Digits Correct Per Minute			
	Mean	Median	Range	Slope
Baseline	40.50	41.40	28.20	
RP	65.02	59.80	36.08	
ICF	40.50	41.40	28.20	
CR	52.80	56.10	23.80	
PP	50.75	50.00	40.20	
Best Treatment RP	71.96	67.00	47.50	10.11

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 17. Summary of means, medians, ranges, and slope of errors per minute for Jeff (instructional level) across conditions

Condition	Errors Per Minute			
	Mean	Median	Range	Slope
Baseline	0.70	0.20	2.40	
RP	0.10	0.00	0.40	
ICF	0.35	0.10	1.20	
CR	0.95	0.60	2.60	
PP	0.35	0.30	0.80	
Best Treatment RP	0.08	0.00	0.40	0.00

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 18. Summary of means, medians, ranges, and slope of rate of acquisition for Jeff (instructional level) across conditions

Condition	Rate of Acquisition			
	Mean	Median	Range	Slope
RP	154.62	145.70	193.08	
ICF	110.65	108.20	147.80	
CR	123.25	122.10	173.60	
PP	119.30	115.70	160.20	
Best Treatment RP	195.65	171.80	292.78	72.60

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 19. Summary of means, medians, ranges, and slope of digits correct per minute for Kayla (instructional level) across conditions

Condition	Digits Correct Per Minute			
	Mean	Median	Range	Slope
Baseline	54.10	57.00	8.80	
RP	79.78	79.13	12.45	
ICF	65.78	65.75	8.40	
CR	78.97	74.57	54.75	
PP	67.43	67.30	22.33	
Best Treatment CR	79.58	82.02	54.75	9.20

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 20. Summary of means, medians, ranges, and slope of errors per minute for Kayla (instructional level) across conditions

Condition	Errors Per Minute			
	Mean	Median	Range	Slope
Baseline	0.70	0.00	2.20	
RP	0.50	0.20	1.60	
ICF	1.35	1.50	2.00	
CR	1.43	1.25	3.20	
PP	1.75	1.90	3.20	
Best Treatment CR	134.00	1.00	3.20	-0.17

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Table 21. Summary of means, medians, ranges, and slope of rate of acquisition for Kayla (instructional level) across conditions

Condition	Rate of Acquisition			
	Mean	Median	Range	Slope
RP	201.84	204.50	239.85	
ICF	160.70	158.60	200.60	
CR	175.96	162.27	252.49	
PP	165.70	168.33	213.33	
Best Treatment CR	220.35	205.14	334.51	86.55

Note. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

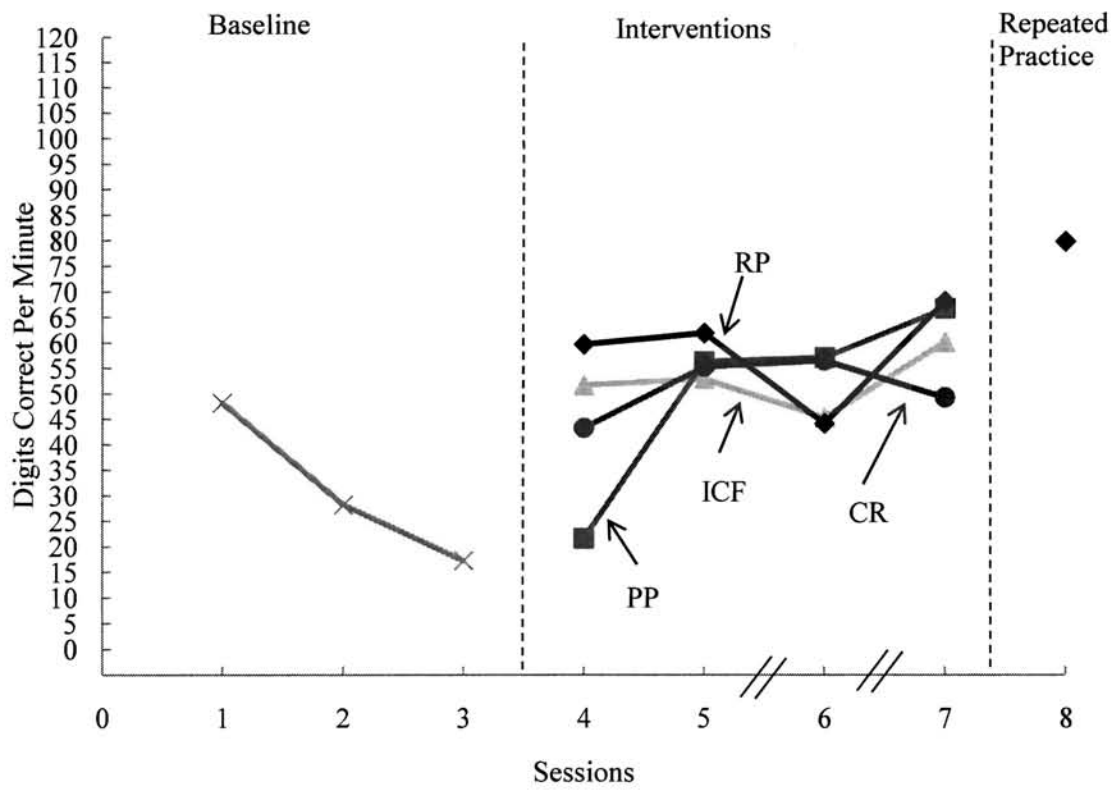


Figure 1. Number of digits correct per minute (DCPM) across experimental conditions for Madeline (frustrational level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

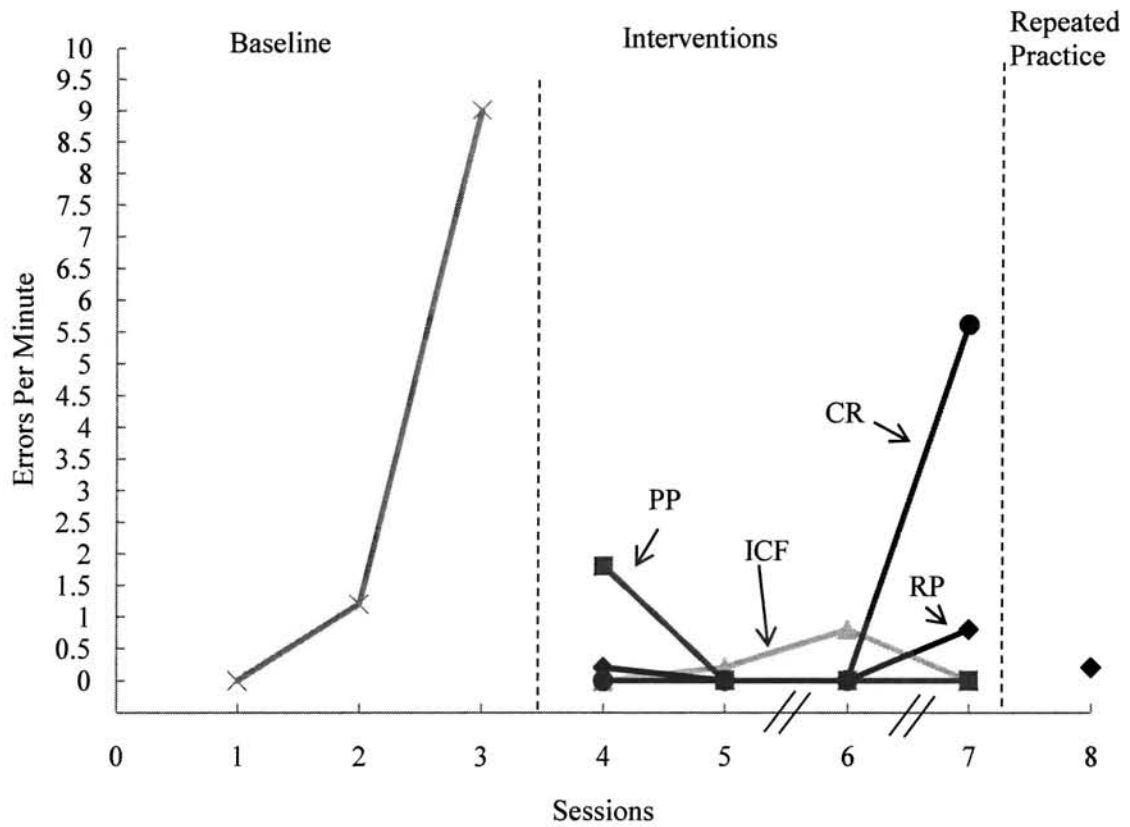


Figure 2. Number of errors per minute (EPM) across experimental conditions for Madeline (frustrational level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

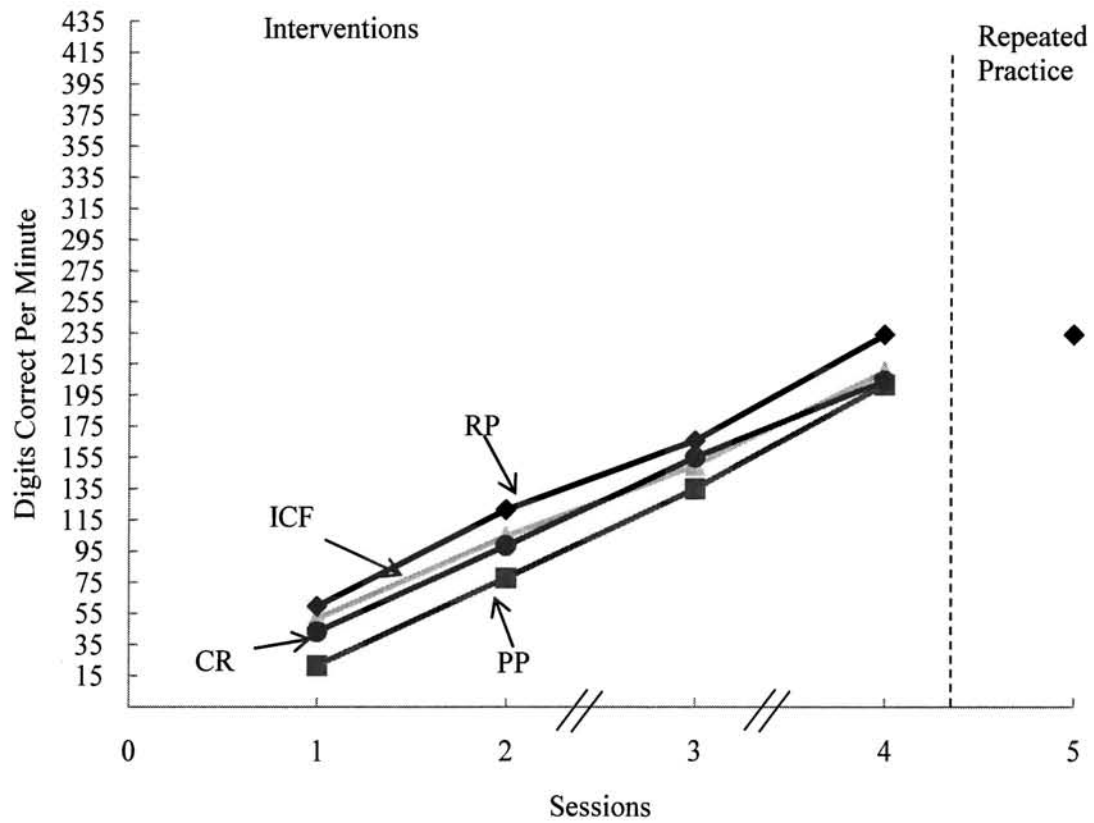


Figure 3. Rate of acquisition (ROA) across experimental conditions for Madeline (frustrational level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

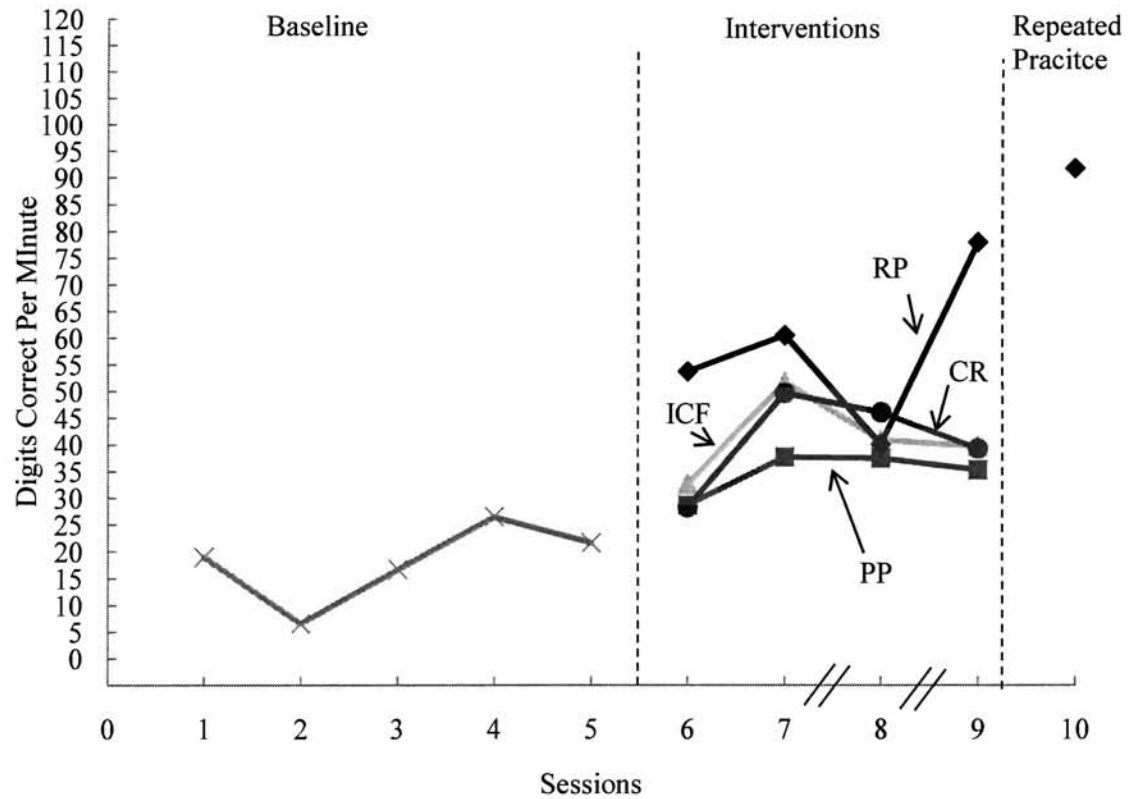


Figure 4. Number of digits correct per minute (DCPM) across experimental conditions for Michael (frustrational level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

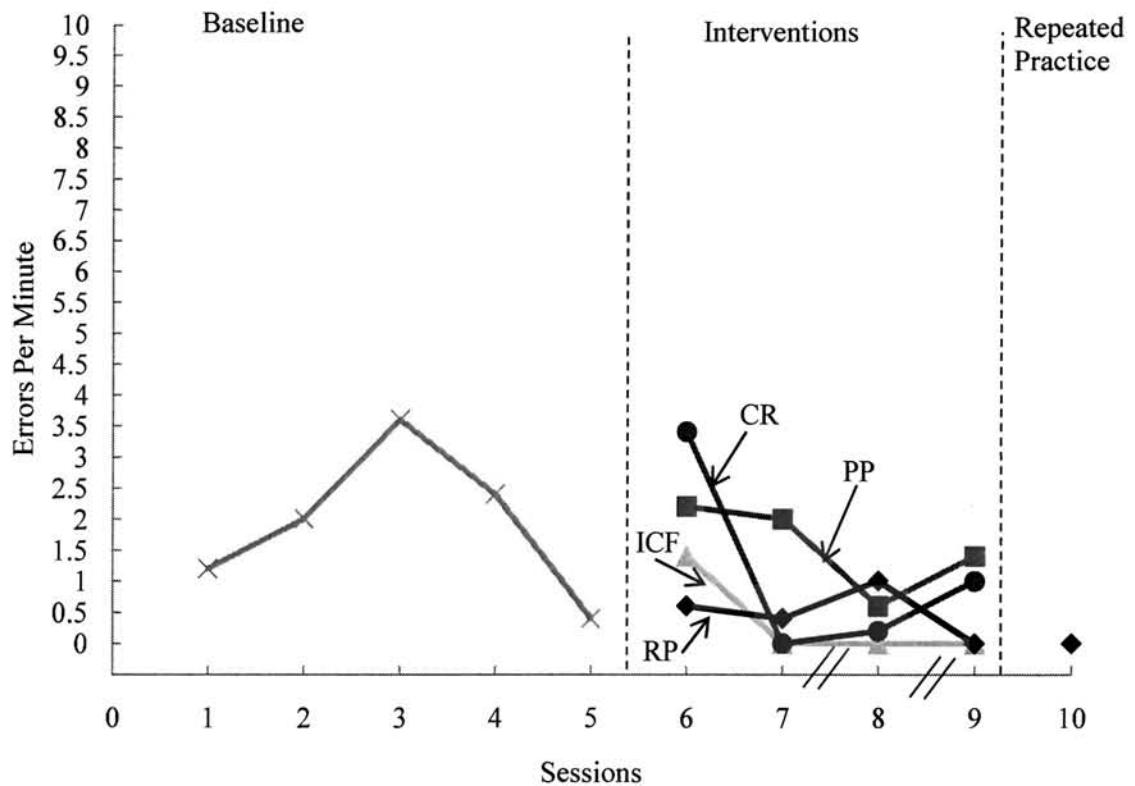


Figure 5. Number of errors per minute (EPM) across experimental conditions for Michael (frustrational level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

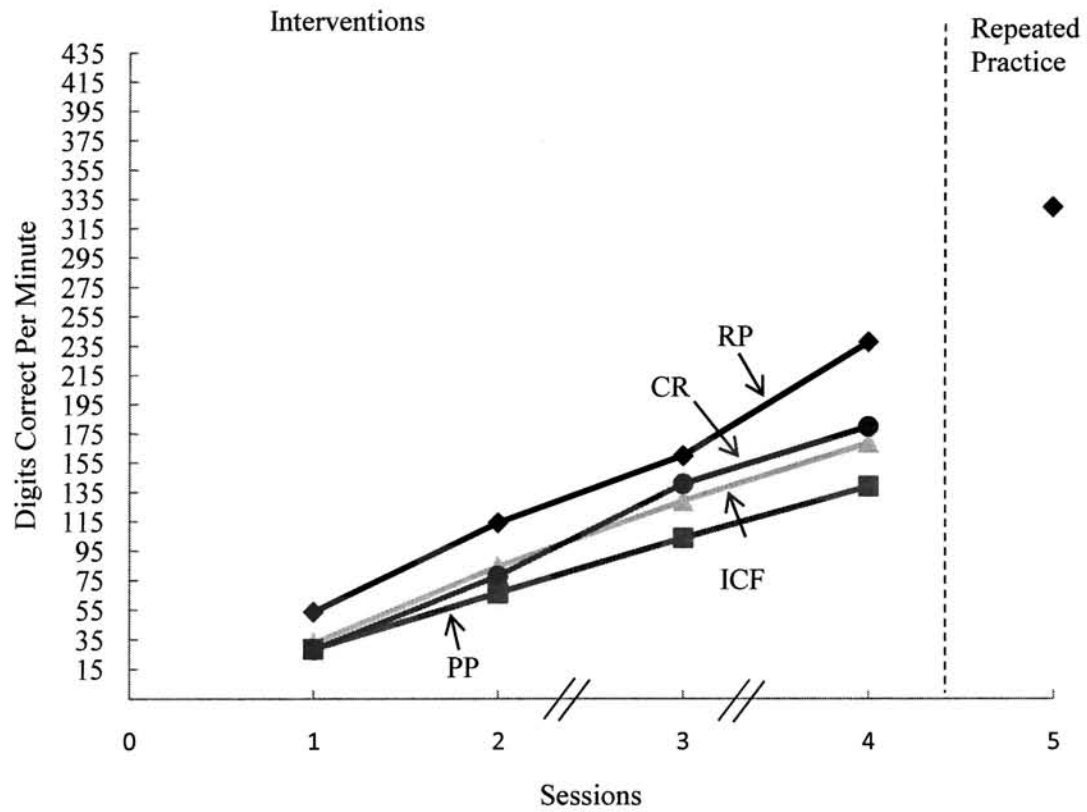


Figure 6. Rate of acquisition (ROA) across experimental conditions for Michael (frustrational level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

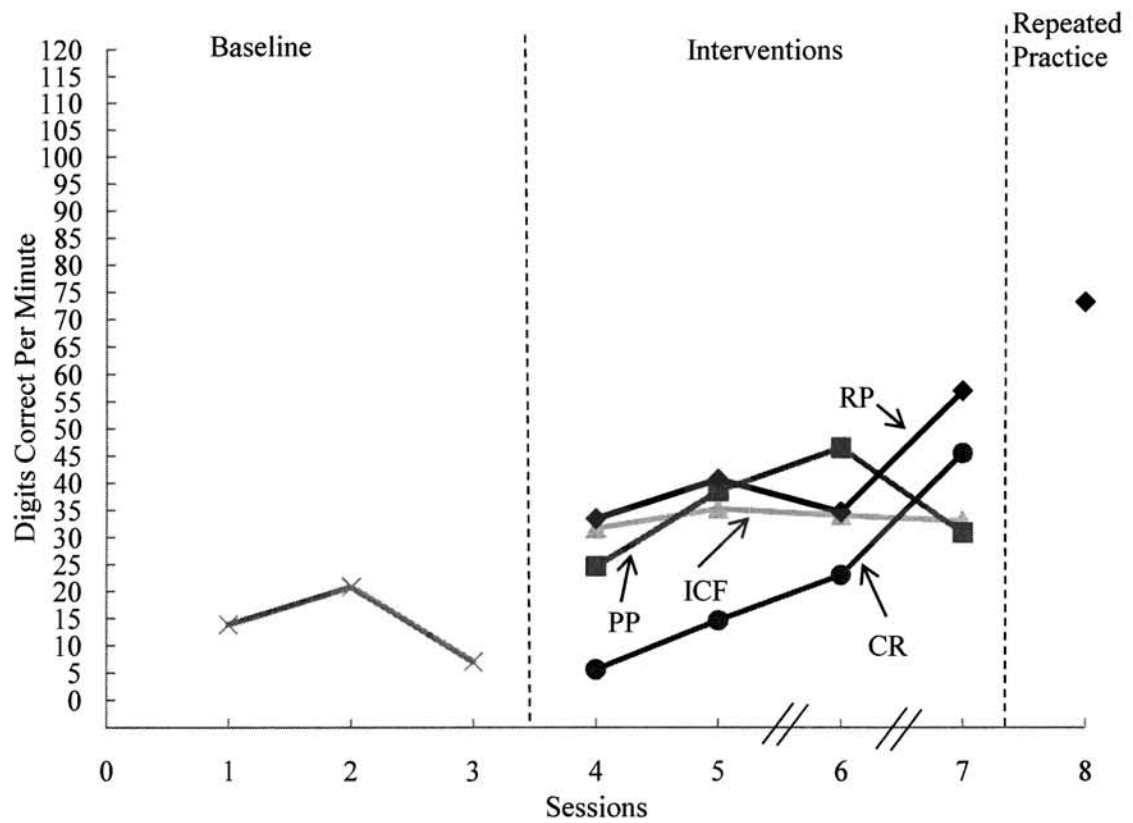


Figure 7. Number of digits correct per minute (DCPM) across experimental conditions for Tony (frustrational level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

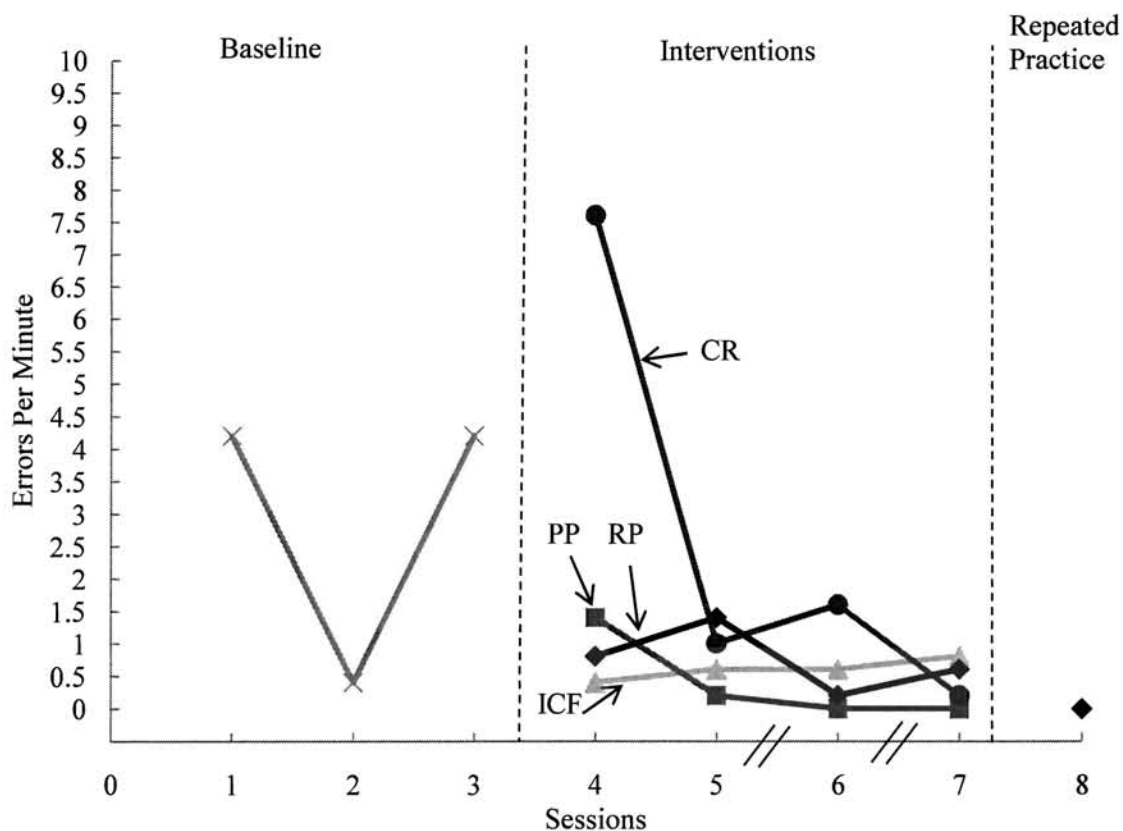


Figure 8. Number of errors per minute (EPM) across experimental conditions for Tony (frustrational level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

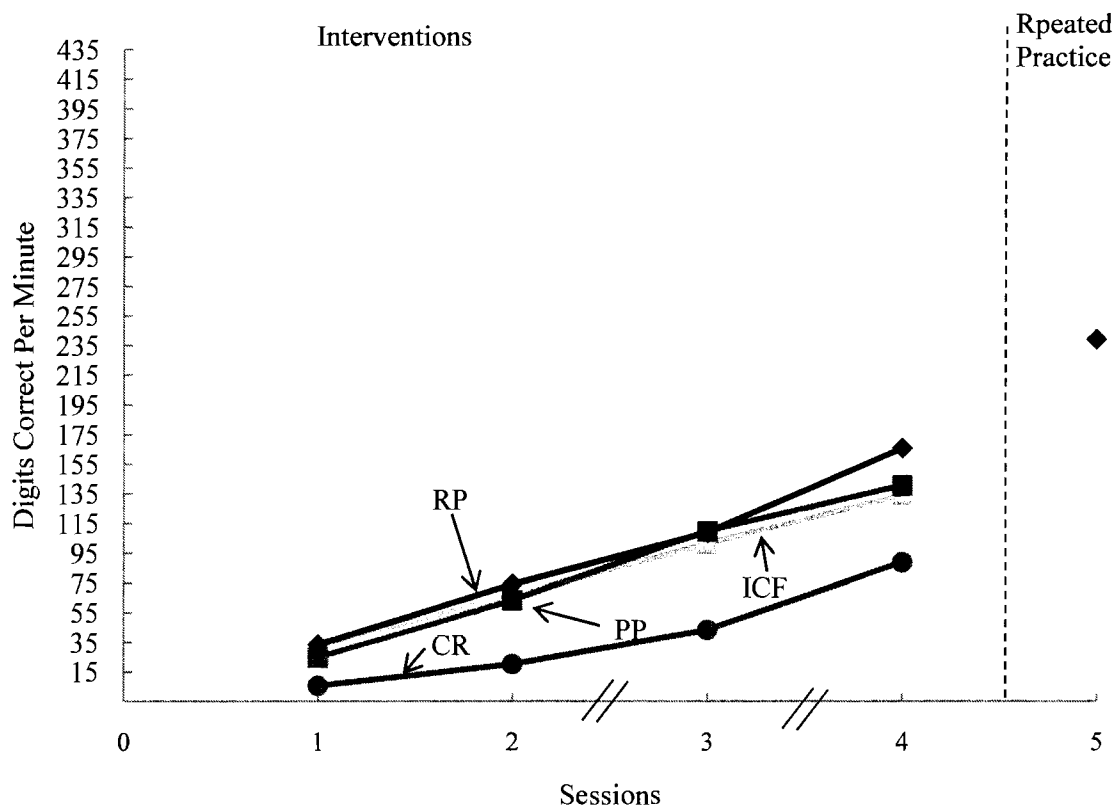


Figure 9. Rate of acquisition (ROA) across experimental conditions for Tony (frustrational level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

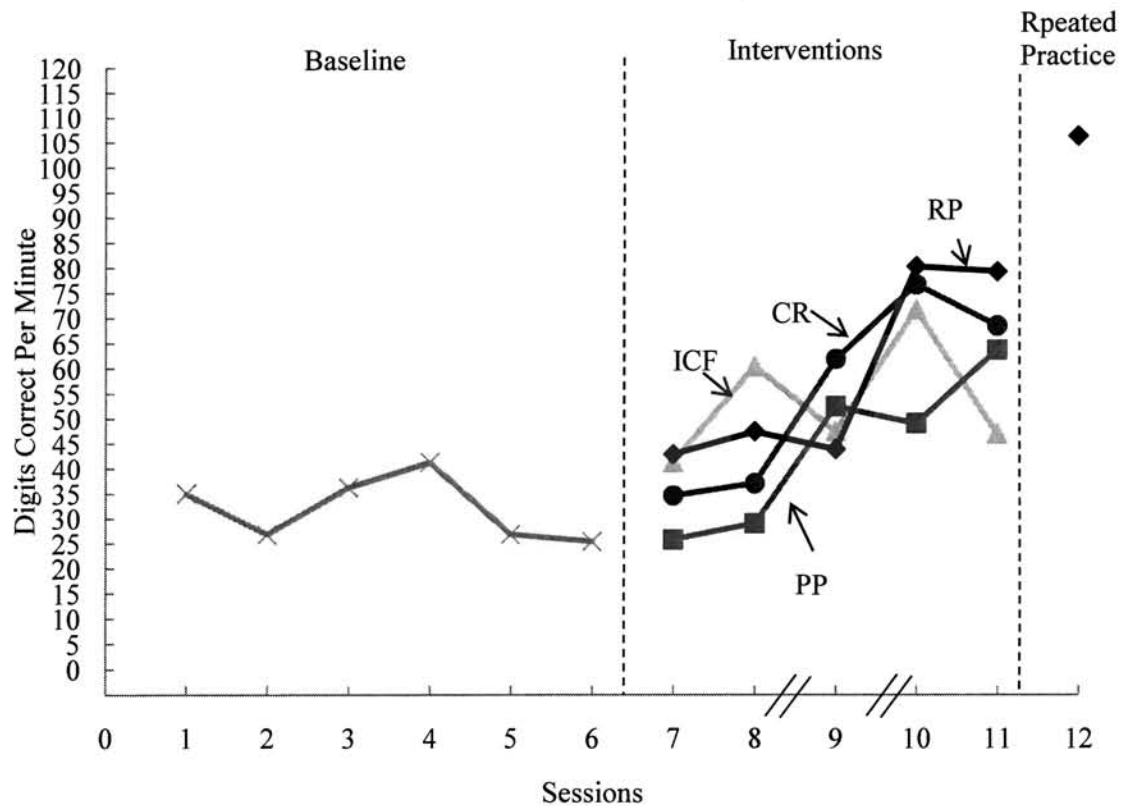


Figure 10. Number of digits correct per minute (DCPM) across experimental conditions for Brianna (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

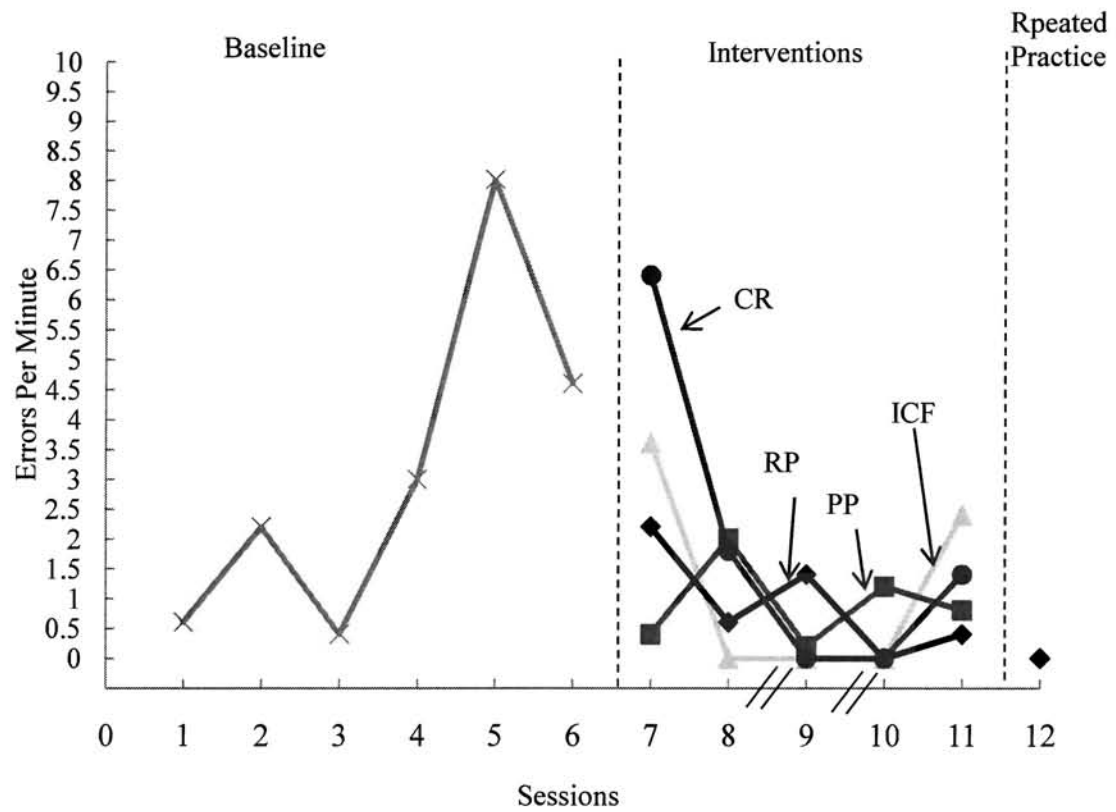


Figure 11. Number of errors per minute (EPM) across experimental conditions for Brianna (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

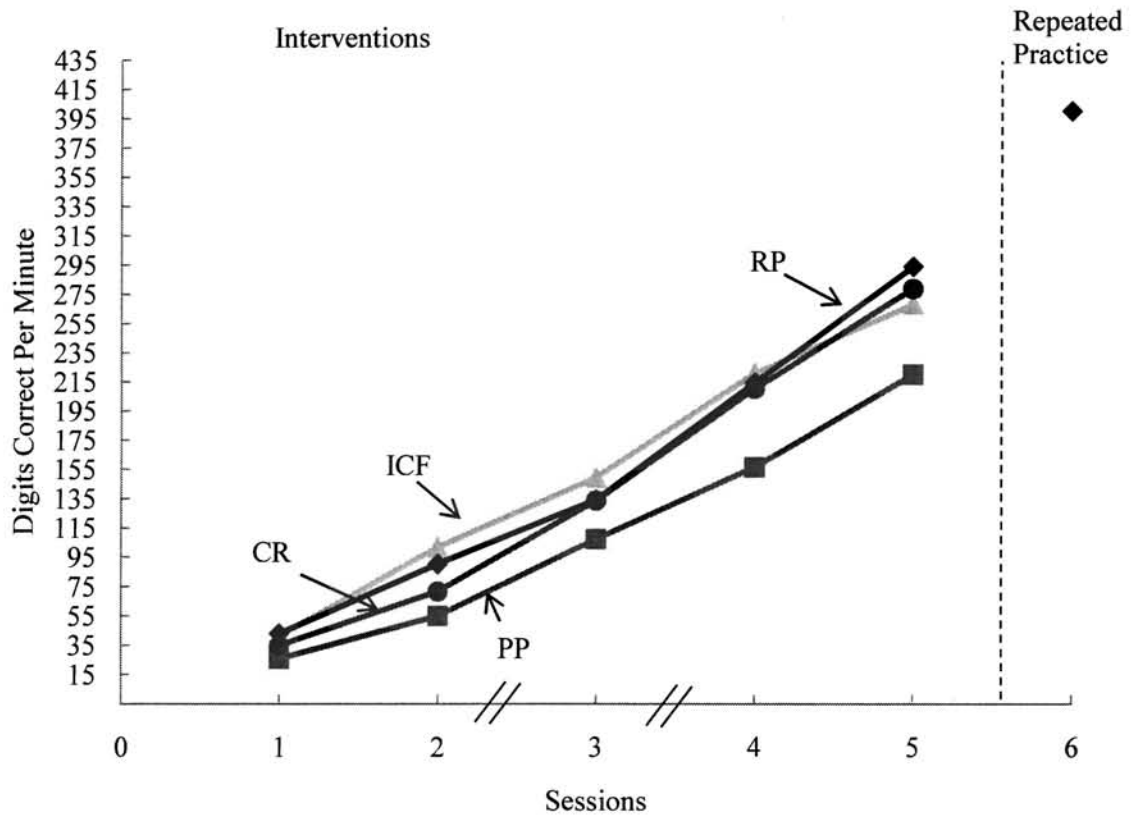


Figure 12. Rate of acquisition (ROA) across experimental conditions for Brianna (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

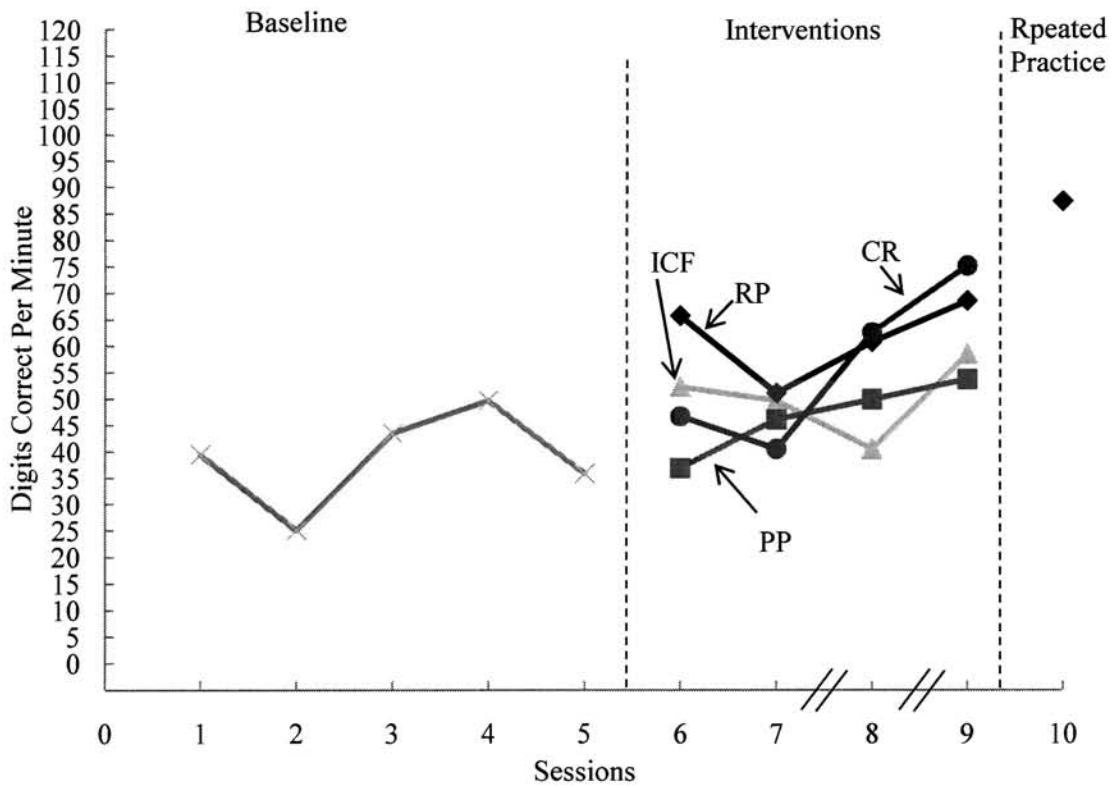


Figure 13. Number of digits correct per minute (DCPM) across experimental conditions for Mayra (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

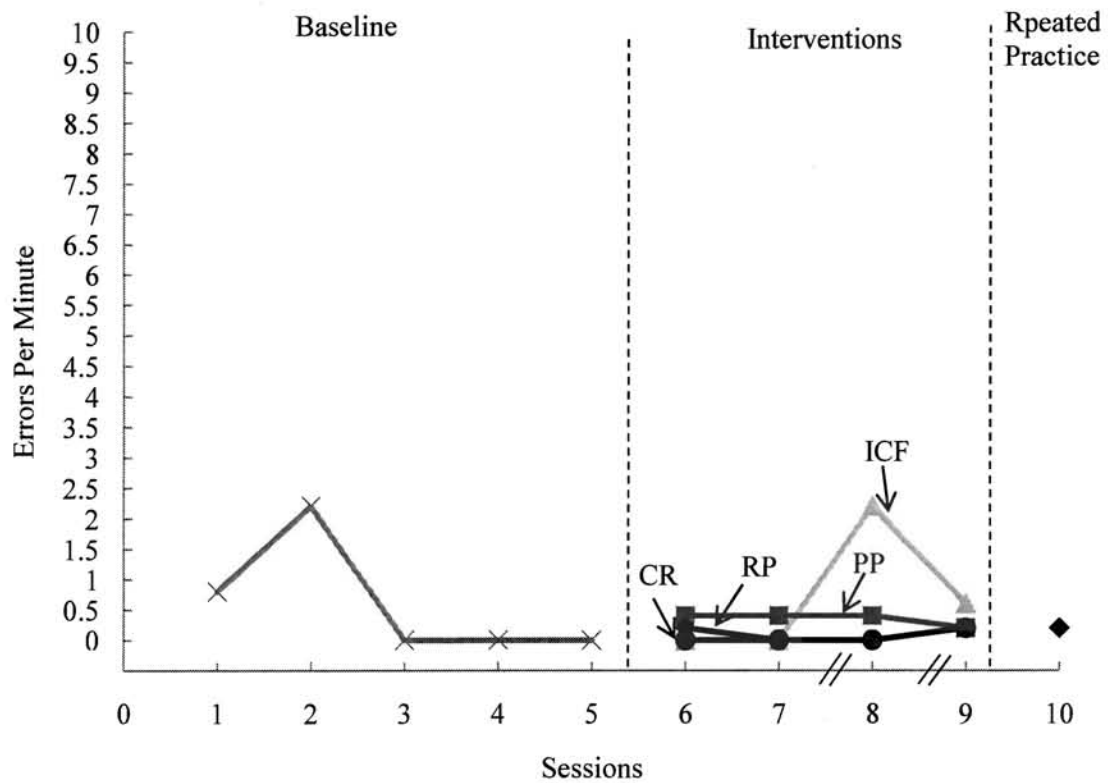


Figure 14. Number of errors per minute (EPM) across experimental conditions for Mayra (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

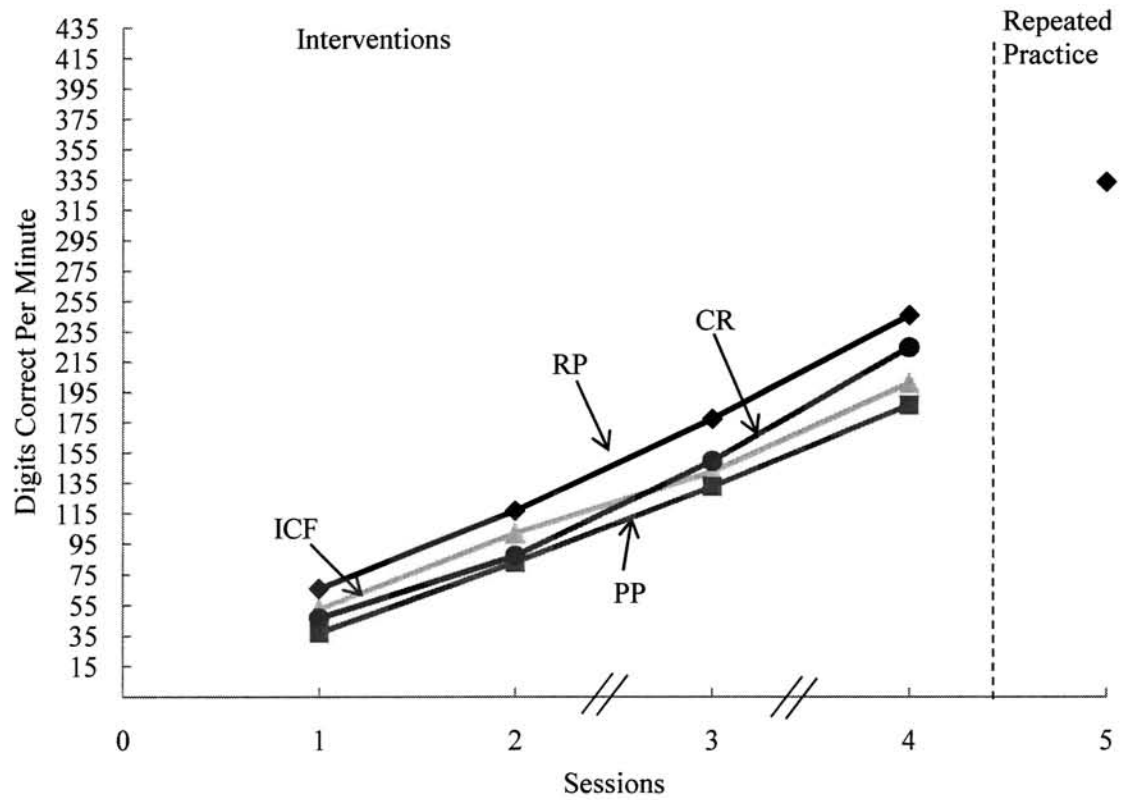


Figure 15. Rate of acquisition (ROA) across experimental conditions for Mayra (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

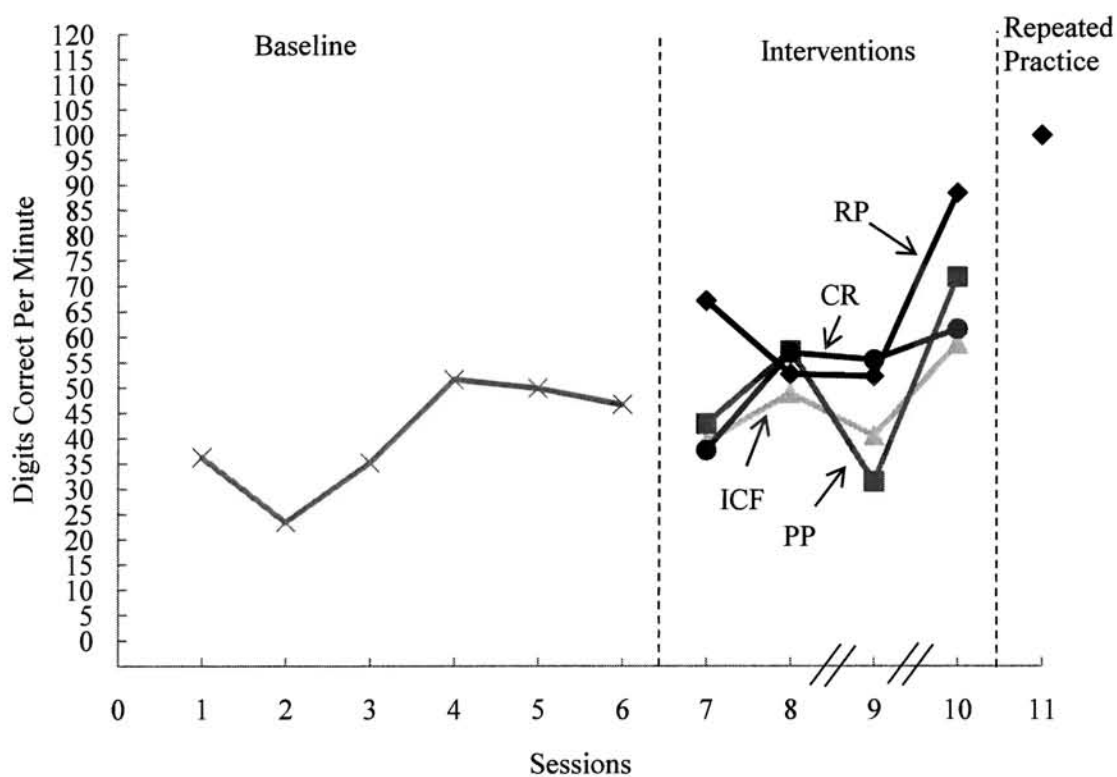


Figure 16. Number of digits correct per minute (DCPM) across experimental conditions for Jeff (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

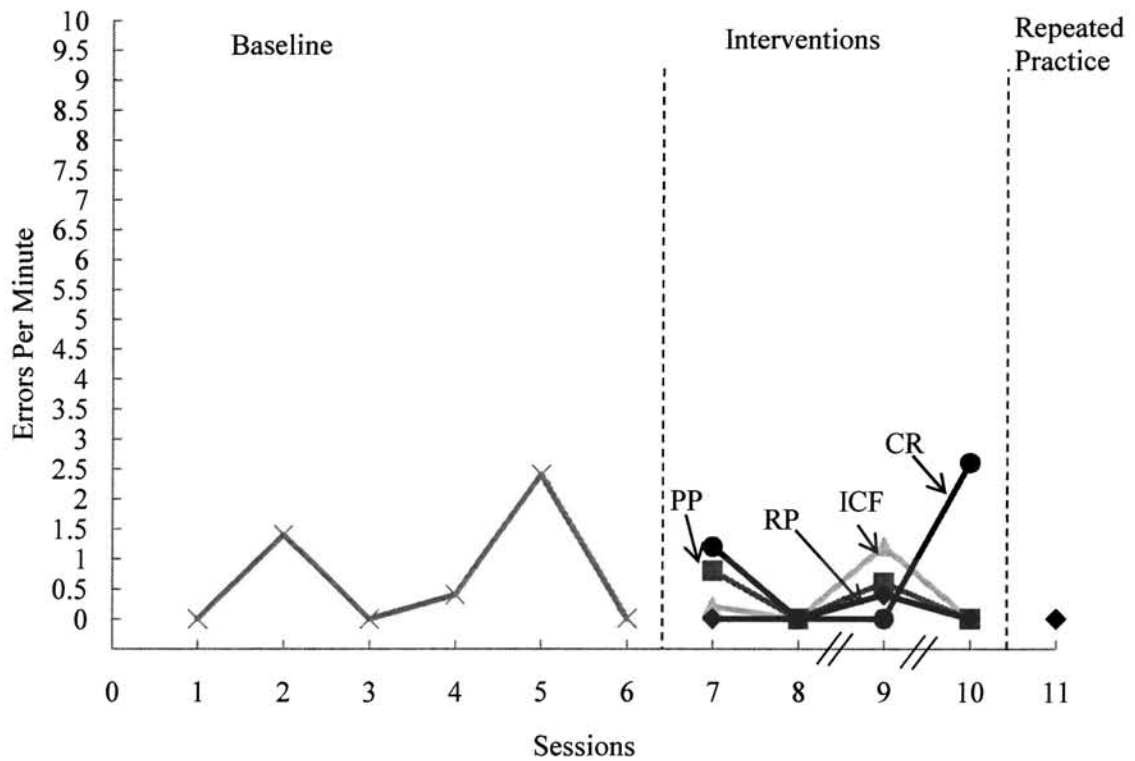


Figure 17. Number of errors per minute (EPM) across experimental conditions for Jeff (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

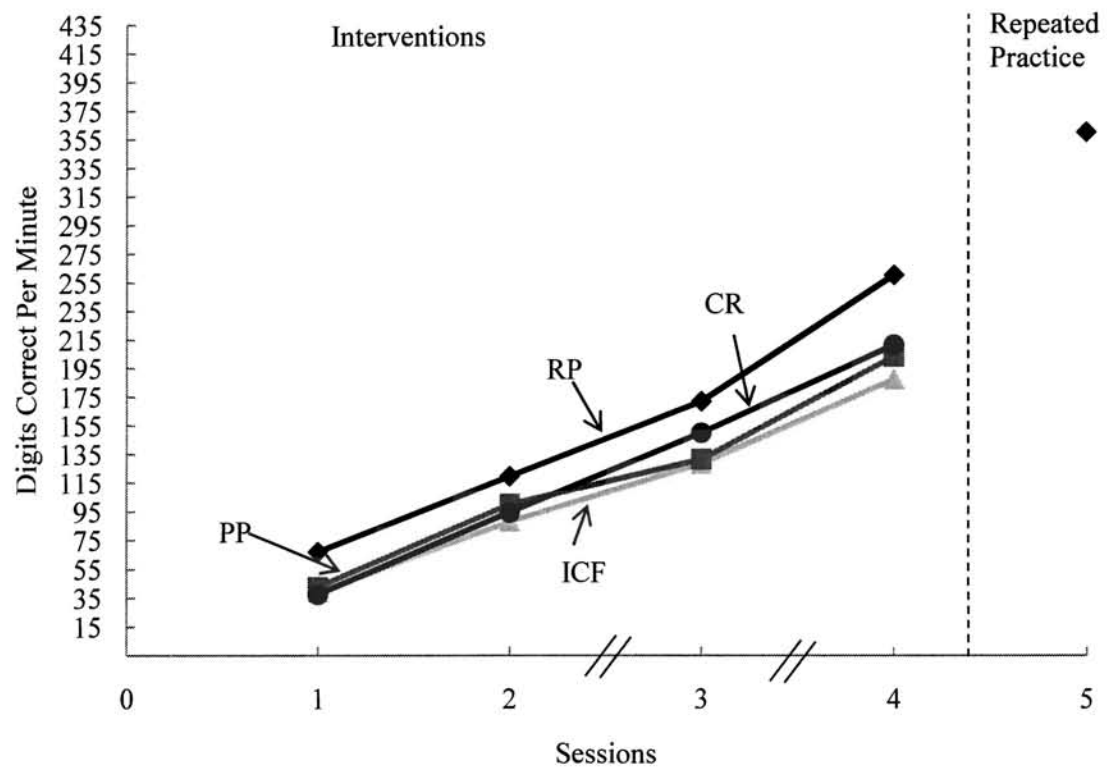


Figure 18. Rate of acquisition (ROA) across experimental conditions for Jeff (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

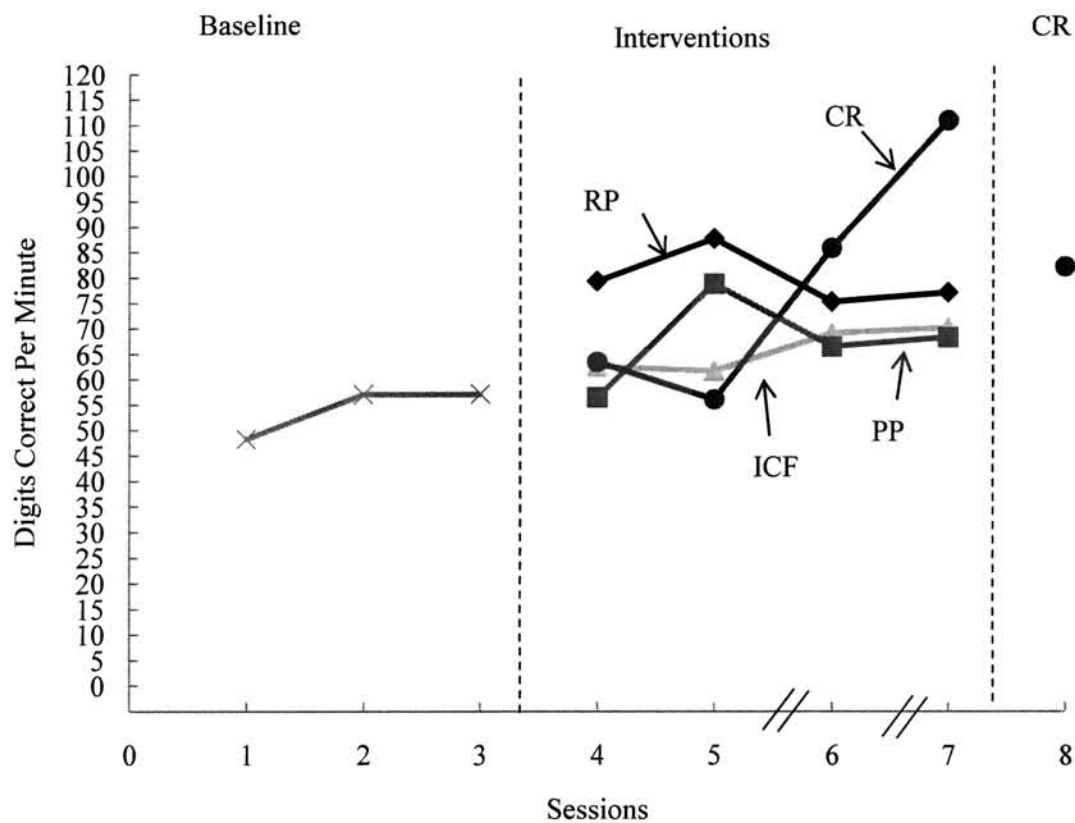


Figure 19. Number of digits correct per minute (DCPM) across experimental conditions for Kayla (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

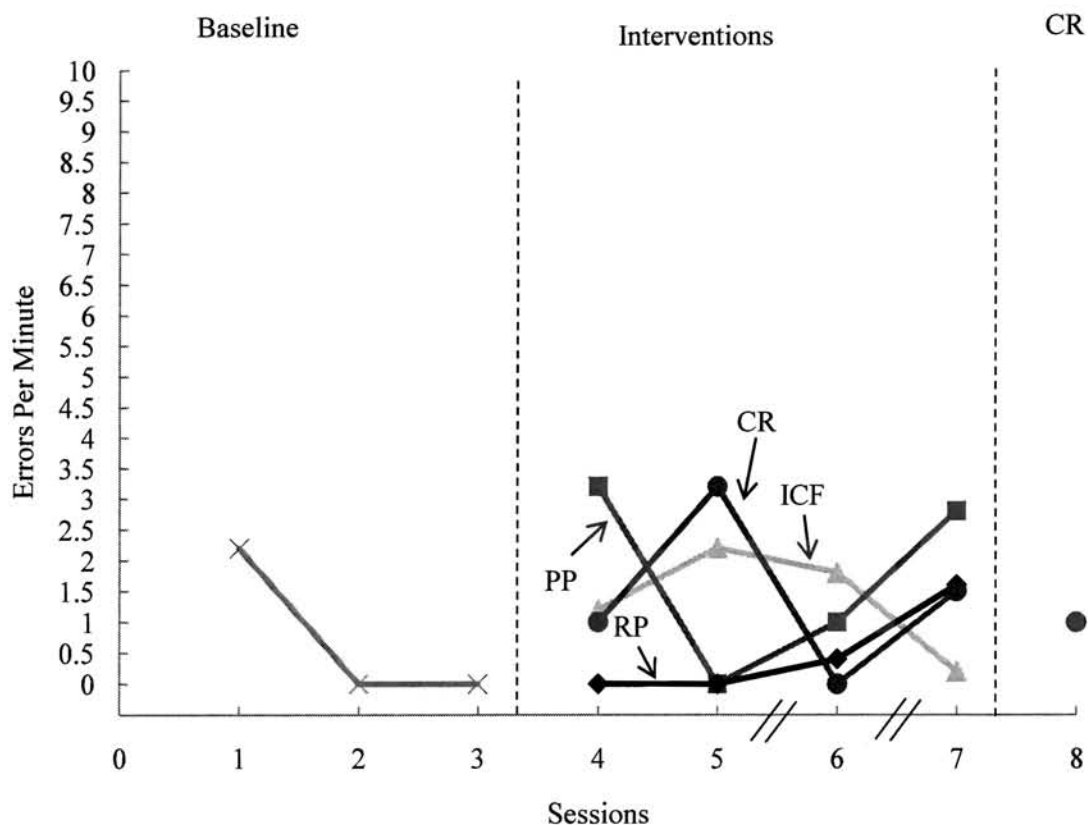


Figure 20. Number of errors per minute (EPM) across experimental conditions for Kayla (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

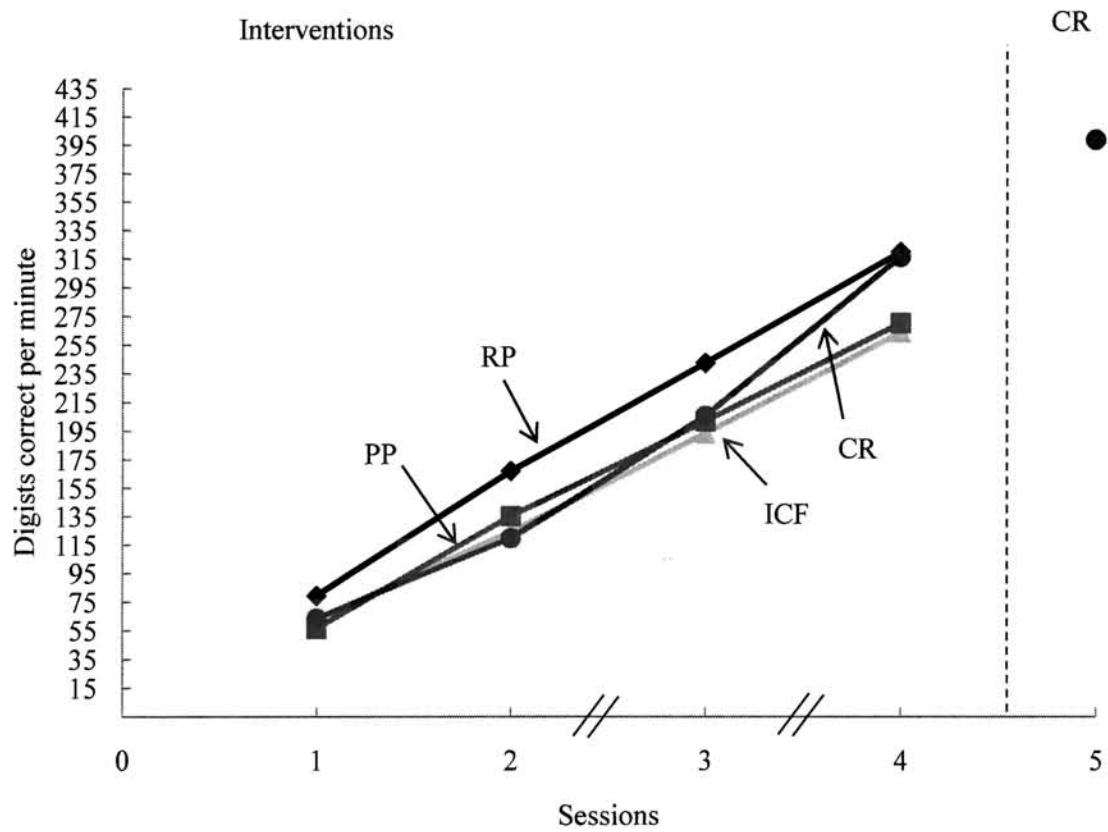


Figure 21. Rate of acquisition (ROA) across experimental conditions for Kayla (instructional level) ending with best treatment. RP = repeated practice; ICF = immediate corrective feedback; CR = contingent reinforcement; PP = problem previewing.

Appendix A

Dear Parents or Legal Guardians,

We will be conducting a study examining methods that could possibly be used to improve your child's ability to solve linear equations. The risks of this study to your child are minimal, but could include your child being anxious about completing the measure. This activity, however, is similar to one a student would experience in the classroom, so the effects should be minimal. The results of this study could help researchers develop improved and effective methods of practicing mathematics skills that can possibly be applied by educators in the future.

I am asking that your child, _____, participate in this study, which will take about three hours total, approximately 50 minutes each week. The study will be conducted at your child's school over a few weeks. I will also be video recording the session to ensure the methods are being used the same way for each student. Six months after the completion of the study, the tapes will be destroyed.

Consent to participate in this study is completely voluntary. If you do not want your child to participate in this study there will be no penalty. Your child may also choose to withdraw from the study at anytime without penalty. The results of the study may be published, but there will be no identifying information included in this publication. In other words, your child's name and the name of his or her school will not be used.

If you have any questions concerning this study, please feel free to contact me at bcmckenna@eiu.edu or (630) 564-4646. You can also contact Dr. Kristin Johnson-Gros at kjohnsongros@eiu.edu or (217) 581-8511. If you have any questions about you or your child's rights as a subject/participant in this research or if you feel you or your child have been placed at risk, you can contact the Office of Research and Sponsored Programs at Eastern Illinois University at (217) 581-8453.

Sincerely,

Bridget McKenna
School Psychology Graduate Student
Psychology Intern

Please return bottom slip by **TUESDAY NOVEMBER 23RD**

_____ I give consent for my child _____ to participate in the above study.

_____ I do not give consent for my child _____ to participate in the above study.

Signature

Date

Appendix B

Dear Student,

I am asking for your help in a short study. We hope to learn how a couple of linear equation assignments can help improve your mathematics skills. If you agree to participate you will be videotaped. After six months of completion of the study the tapes will be destroyed. Your help in this study is voluntary. You will not be hurt, nor will your grade be lowered, if you refuse to participate in this study. At any time during the study you can stop without penalty.

Please ask any questions you may have. Please tell me if you want to help with this study. Sign the bottom of this form and check yes if you want to help and no if you do not want to help. If you do not want to help, or stop at any time, you will return to your classroom.

Thank you for your help!

Bridget McKenna
School Psychology Graduate Student

_____ I agree to participate in this study.

_____ I do not agree to participate in this study.

Your teacher: _____

Your school: _____

Print Your Name

Sign Your Name

Date

Appendix C

Please solve for X and Y

$$\begin{aligned}x &= -8y + 64 \\ -2x - 8y &= -72\end{aligned}$$

$$\begin{aligned}x &= 3y - 6 \\ -10x - 9y &= -57\end{aligned}$$

$$\begin{aligned}y &= 2x + 8 \\ 7y + 2x &= 8\end{aligned}$$

$$\begin{aligned}x &= 7y - 17 \\ -10x + 6y &= -22\end{aligned}$$

$$\begin{aligned}y &= -6x - 17 \\ -8y - 5x &= 7\end{aligned}$$

$$\begin{aligned}y &= -6x + 5 \\ -10y - 9x &= -50\end{aligned}$$

$$\begin{aligned}x &= 5y + 37 \\ 3x - 5y &= 51\end{aligned}$$

$$\begin{aligned}x &= -8y - 59 \\ 9x - 7y &= 101\end{aligned}$$

$$\begin{aligned}x &= -8y - 25 \\ -5x - 5y &= -15\end{aligned}$$

$$\begin{aligned}x &= -6y - 33 \\ -5x - 2y &= -3\end{aligned}$$

Please solve for X and Y

$$\begin{aligned}x &= 2y - 7 \\4x + 6y &= 56\end{aligned}$$

$$\begin{aligned}x &= -9y + 60 \\9x - 8y &= 6\end{aligned}$$

$$\begin{aligned}x &= 4y + 35 \\9x - 6y &= 105\end{aligned}$$

$$\begin{aligned}y &= -4x + 5 \\-6y + 9x &= -63\end{aligned}$$

$$\begin{aligned}x &= 8y + 39 \\-9x - 3y &= -51\end{aligned}$$

$$\begin{aligned}x &= 4y - 7 \\-4x + 7y &= 1\end{aligned}$$

$$\begin{aligned}y &= 6x + 64 \\-7y + 9x &= -118\end{aligned}$$

$$\begin{aligned}x &= 4y - 11 \\3x - 6y &= -15\end{aligned}$$

$$\begin{aligned}x &= -10y - 8 \\-4x - 10y &= 2\end{aligned}$$

$$\begin{aligned}x &= 9y + 51 \\-9x + 4y &= -74\end{aligned}$$

Please solve for X and Y

$$-14x - 4y = 26$$

$$-7x + 9y = -97$$

$$-16y + 2x = 138$$

$$4y - 10x = -6$$

$$7x + 20y = -203$$

$$-3x - 4y = 55$$

$$-6y + 9x = 111$$

$$2y + 2x = -2$$

$$9y - 21x = 156$$

$$4y - 7x = 53$$

$$3y + 9x = 42$$

$$-4y + 3x = 64$$

$$6y + 16x = -174$$

$$-6y - 8x = 102$$

$$8x - 50y = 258$$

$$-6x - 10y = 44$$

$$4x - 50y = 314$$

$$9x - 10y = -11$$

$$8x - 4y = -12$$

$$5x - 2y = -12$$

Please solve for X and Y

$$-16x - 8y = -176$$

$$4x + 9y = 72$$

$$6x - 25y = 113$$

$$9x + 5y = -43$$

$$2x + 20y = -208$$

$$-3x + 5y = -38$$

$$12x - 7y = -140$$

$$6x + 4y = -10$$

$$10y - 8x = -108$$

$$-2y - 4x = 16$$

$$3x - 15y = -108$$

$$2x - 5y = -37$$

$$7y - 12x = 82$$

$$-4y + 4x = -24$$

$$8y - 6x = 6$$

$$8y + 2x = 30$$

$$8y - 15x = 122$$

$$5y - 3x = 38$$

$$9y - 16x = 49$$

$$8y - 4x = -28$$

Please solve for X and Y

$$-14x - 4y = 26$$

$$-7x + 9y = -97$$

$$-16y + 2x = 138$$

$$4y - 10x = -6$$

$$7x + 20y = -203$$

$$-3x - 4y = 55$$

$$-6y + 9x = 111$$

$$2y + 2x = -2$$

$$9y - 21x = 156$$

$$4y - 7x = 53$$

$$3y + 9x = 42$$

$$-4y + 3x = 64$$

$$6y + 16x = -174$$

$$-6y - 8x = 102$$

$$8x - 50y = 258$$

$$-6x - 10y = 44$$

$$4x - 50y = 314$$

$$9x - 10y = -11$$

$$8x - 4y = -12$$

$$5x - 2y = -12$$

Please solve for X and Y

$$-16x - 8y = -176$$

$$4x + 9y = 72$$

$$6x - 25y = 113$$

$$9x + 5y = -43$$

$$2x + 20y = -208$$

$$-3x + 5y = -38$$

$$12x - 7y = -140$$

$$6x + 4y = -10$$

$$10y - 8x = -108$$

$$-2y - 4x = 16$$

$$3x - 15y = -108$$

$$2x - 5y = -37$$

$$7y - 12x = 82$$

$$-4y + 4x = -24$$

$$8y - 6x = 6$$

$$8y + 2x = 30$$

$$8y - 15x = 122$$

$$5y - 3x = 38$$

$$9y - 16x = 49$$

$$8y - 4x = -28$$

Please solve for X and Y

$$\begin{aligned}2x - 6y &= 48 \\ -5x + 3y &= -12\end{aligned}$$

$$\begin{aligned}-5x - 6y &= -87 \\ 1x + 7y &= 58\end{aligned}$$

$$\begin{aligned}6y + 14x &= 114 \\ 7y + 7x &= 77\end{aligned}$$

$$\begin{aligned}2x + 36y &= -356 \\ -7x + 9y &= -104\end{aligned}$$

$$\begin{aligned}8x - 4y &= -20 \\ -4x - 3y &= 5\end{aligned}$$

$$\begin{aligned}12y - 10x &= 16 \\ -3y - 10x &= -29\end{aligned}$$

$$\begin{aligned}4x + 6y &= 32 \\ -2x + 2y &= 14\end{aligned}$$

$$\begin{aligned}6x - 25y &= -255 \\ 4x - 5y &= -65\end{aligned}$$

$$\begin{aligned}-8y + 3x &= -3 \\ 2y + 5x &= -51\end{aligned}$$

$$\begin{aligned}6y + 8x &= -96 \\ -5y - 2x &= 38\end{aligned}$$

Please solve for X and Y

$$9y - 20x = -33$$

$$-9y + 5x = -12$$

$$6x + 14y = 144$$

$$-9x + 7y = 36$$

$$-9y - 2x = -66$$

$$-3y + 3x = -33$$

$$5x + 45y = 445$$

$$-9x + 9y = 9$$

$$-30y + 5x = 310$$

$$-10y - 6x = 88$$

$$-15x - 7y = -65$$

$$-3x - 6y = -36$$

$$-4x - 7y = -64$$

$$-2x + 9y = 18$$

$$-5x - 9y = 46$$

$$1x + 9y = -38$$

$$4x - 36y = 236$$

$$-8x + 9y = -94$$

$$-24x - 6y = 204$$

$$-6x + 6y = 6$$

Please solve for X and Y

$$y = -4x + 10$$

$$-2y + 4x = -8$$

$$x = -2y + 14$$

$$9x - 4y = 16$$

$$x = -8y - 53$$

$$-8x - 10y = 46$$

$$x = -9y - 29$$

$$-6x + 5y = -62$$

$$x = -8y + 71$$

$$-6x + 2y = -26$$

$$y = 5x + 9$$

$$9y + 5x = 31$$

$$y = -9x + 60$$

$$-4y + 6x = 12$$

$$y = 5x - 29$$

$$-4y - 3x = -45$$

$$y = 4x - 2$$

$$-8y - 4x = -56$$

$$y = 6x - 15$$

$$7y + 6x = 87$$

Please solve for X and Y

$$y = 7x - 20$$

$$5y - 7x = 12$$

$$y = 4x + 24$$

$$8y - 5x = 57$$

$$y = 3x - 20$$

$$6y - 7x = -32$$

$$x = -10y + 12$$

$$4x - 4y = 4$$

$$y = 6x - 24$$

$$9y + 5x = 79$$

$$x = -10y + 53$$

$$-8x + 5y = 1$$

$$y = 5x + 43$$

$$-4y - 5x = 28$$

$$x = 4y - 16$$

$$8x + 7y = 106$$

$$y = -10x + 29$$

$$2y + 9x = 36$$

$$y = -2x - 12$$

$$-7y + 6x = -56$$

Please solve for X and Y

-

$$20x + 5y = 135$$

$$-10x + 6y = 36$$

$$5y + 36x = 150$$

$$-3y + 9x = 63$$

$$2x - 32y = 82$$

$$6x + 8y = -66$$

$$15y + 5x = -5$$

$$-3y + 8x = 46$$

$$-40y + 4x = -156$$

$$-10y + 3x = -37$$

$$9y - 10x = 47$$

$$-3y - 5x = 1$$

$$6y - 8x = -74$$

$$-2y + 6x = 38$$

$$9x - 16y = 3$$

$$2x - 8y = 14$$

$$6x + 2y = -14$$

$$-2x - 3y = -14$$

$$12y - 7x = 35$$

$$4y + 9x = 35$$

Please solve for X and Y

$$9y + 21x = 93$$

$$-5y + 7x = 23$$

$$-10y - 4x = 62$$

$$2y - 3x = -39$$

$$8y - 15x = 21$$

$$-3y - 3x = 18$$

$$-20x + 4y = -44$$

$$-5x - 9y = -51$$

$$3y + 9x = 15$$

$$9y - 3x = 15$$

$$4x + 9y = -103$$

$$5x + 3y = -71$$

$$-20y - 7x = -1$$

$$-4y - 10x = -26$$

$$6x - 3y = -66$$

$$-3x - 2y = 19$$

$$8y - 4x = 72$$

$$9y + 2x = 42$$

$$9y + 24x = -192$$

$$2y - 6x = 14$$

Please solve for X and Y

$$y = -6x + 19$$

$$-2y - 2x = -8$$

$$y = -10x - 46$$

$$7y + 3x = 13$$

$$y = 3x - 3$$

$$2y + 2x = 26$$

$$y = 6x - 28$$

$$-6y + 9x = 33$$

$$y = 8x + 13$$

$$9y + 6x = 39$$

$$y = 5x + 39$$

$$-6y + 4x = -78$$

$$x = 9y - 27$$

$$-5x - 8y = -77$$

$$x = 5y + 38$$

$$-2x + 9y = -69$$

$$x = -4y + 17$$

$$-2x + 5y = 18$$

$$x = 8y + 64$$

$$-4x - 9y = 31$$

Please solve for X and Y

$$y = 9x + 98$$

$$-8y - 9x = 26$$

$$x = -8y + 60$$

$$5x - 9y = -43$$

$$x = -4y + 30$$

$$-6x - 4y = -40$$

$$y = -3x + 5$$

$$6y - 6x = 30$$

$$12x - 4y = 88$$

$$4x + 7y = 46$$

$$-24x + 8y = 256$$

$$-8x + 5y = 97$$

$$-30y + 3x = -153$$

$$-6y - 3x = -63$$

$$10x - 5y = 30$$

$$-2x - 7y = -38$$

$$9x - 12y = 45$$

$$-6x - 6y = 54$$

$$9y - 24x = -159$$

$$-6y + 8x = 74$$

Please solve for X and Y

$$x = 5y - 6$$

$$-6x + 4y = -16$$

$$y = 3x - 16$$

$$-8y + 3x = -40$$

$$y = -9x - 6$$

$$-9y - 8x = -19$$

$$y = -9x - 22$$

$$-6y - 4x = -18$$

$$x = -2y - 1$$

$$-9x - 6y = -51$$

$$y = -2x + 21$$

$$-7y + 8x = 51$$

$$x = -4y + 20$$

$$3x - 7y = -16$$

$$x = 3y + 13$$

$$9x + 6y = 18$$

$$x = 6y - 13$$

$$-6x - 2y = -36$$

$$x = 4y + 0$$

$$4x + 3y = 19$$

Please solve for X and Y

$$y = -4x + 24$$

$$-9y - 4x = -88$$

$$x = -10y - 26$$

$$4x - 10y = 46$$

$$y = 2x + 2$$

$$-2y - 5x = -13$$

$$y = -8x + 24$$

$$-7y + 5x = -46$$

$$y = -7x + 45$$

$$7y + 5x = 51$$

$$y = -2x + 20$$

$$2y - 10x = -44$$

$$y = 4x + 9$$

$$-9y - 4x = -41$$

$$y = -6x + 53$$

$$-4y - 6x = -68$$

$$x = 8y + 40$$

$$-8x - 7y = -36$$

$$y = 8x + 88$$

$$-6y - 6x = 12$$

Please solve for X and Y

$$-15x + 3y = 111$$

$$-5x - 7y = 101$$

$$25x - 6y = 205$$

$$5x - 2y = 45$$

$$-8x + 6y = 20$$

$$2x + 4y = 28$$

$$3x - 9y = 30$$

$$2x + 3y = 11$$

\

$$-8x + 3y = -39$$

$$-2x + 5y = 3$$

$$2y - 9x = -11$$

$$-10y + 3x = 97$$

$$-6y - 4x = -24$$

$$2y + 9x = 77$$

$$2x + 32y = 50$$

$$-4x + 8y = 44$$

$$6y - 8x = -4$$

$$3y - 3x = -9$$

$$2y + 8x = -88$$

$$2y + 4x = -48$$

Please solve for X and Y

$$9x + 20y = -198$$

$$-3x - 4y = 42$$

$$9x - 8y = -74$$

$$8x + 2y = -84$$

$$7y - 12x = 126$$

$$4y + 4x = -4$$

$$5x - 30y = -70$$

$$-6x + 6y = 24$$

$$8x - 32y = 224$$

$$-2x - 8y = 40$$

$$2x - 30y = -192$$

$$-10x - 6y = 24$$

$$7x - 40y = 144$$

$$2x - 10y = 34$$

$$8y + 21x = 149$$

$$5y - 7x = -88$$

$$12x + 9y = -126$$

$$-4x - 5y = 54$$

$$6x + 25y = -180$$

$$-6x + 5y = 0$$

Please solve for X and Y

$$y = 2x + 17$$

$$-4y + 7x = -63$$

$$y = 6x - 51$$

$$2y + 8x = 78$$

$$y = 4x - 9$$

$$-6y - 3x = -27$$

$$y = -9x - 21$$

$$9y + 7x = 33$$

$$x = 2y + 0$$

$$-10x + 7y = -39$$

$$y = 7x + 0$$

$$5y - 10x = 25$$

$$y = -5x - 2$$

$$5y - 8x = 23$$

$$y = -7x - 66$$

$$2y - 10x = 108$$

$$x = -5y + 14$$

$$5x - 4y = 41$$

$$x = -5y + 46$$

$$-9x - 10y = -134$$

Appendix D

Contingent Reinforcement

___ Researcher said to participant “This bag contains several pieces of paper with names of items you could earn. If your performance today is better than before, you will be able to have this item.

___ Researcher gave worksheet to participant

___ Researcher said to the participant “You will have five minutes to complete this worksheet, please solve for X and Y. Try to solve as many problems as you can within the time limit. When I tell you to stop, please put your pencil down.”

___ Researcher started stop watch as soon as participant began worksheet

___ Researcher stopped stop watch after 5 minutes

___ Research told participant to stop working after 5 minutes had elapsed

___ Researcher scored participant's worksheet and calculated DCPM and EPM

___ Researcher compared participant’s current score to goal score (15% over previous performance).

___ If participant increased his/her performance by 15% or more, the researcher had the participant select a piece of paper out of the container.

___ The participant was given the item he/she selected

___ The researcher returned the piece of paper to the container.

Appendix E

Repeated practice

___ Researcher gave first worksheet to participant

___ Researcher said to the participant “You will have five minutes to complete this worksheet, please solve for X and Y. Try to solve as many problems as you can within the time limit. When I tell you to stop, please put your pencil down.”

___ Researcher started stop watch as soon as participant began worksheet

___ Researcher stopped stop watch after 5 minutes

___ Research told participant to stop working after 5 minutes had elapsed

___ The researcher gave the participant the second worksheet

___ Researcher said to the participant “You will have five minutes to complete this worksheet, please solve for X and Y. Try to solve as many problems as you can within the time limit. When I tell you to stop, please put your pencil down.”

___ Researcher started stop watch as soon as participant began worksheet

___ While participant completed second worksheet, researcher scored participant’s first worksheet and calculated DCPM and EPM

___ Researcher stopped stop watch after 5 minutes

___ Research told participant to stop working after 5 minutes had elapsed

___ Researcher gave the participant the third worksheet

___ Researcher said to the participant “You will have five minutes to complete this worksheet, please solve for X and Y. Try to solve as many problems as you can within the time limit. When I tell you to stop, please put your pencil down.”

___ Researcher started stop watch as soon as participant began the third worksheet

___ While participant completed third worksheet, researcher scored participant’s second worksheet and calculated DCPM and EPM

___ Researcher stopped stop watch after 5 minutes

___ Research told participant to stop working after 5 minutes had elapsed

___ Researcher gave the participant the fourth worksheet

___ Researcher said to the participant “You will have five minutes to complete this worksheet, please solve for X and Y. Try to solve as many problems as you can within the time limit. When I tell you to stop, please put your pencil down.”

___ Researcher started stop watch as soon as participant began worksheet

___ While participant completed fourth worksheet, researcher scored participant’s third worksheet and calculated DCPM and EPM

___ Researcher stopped stop watch after 5 minutes

___ Research told participant to stop working after 5 minutes had elapsed

___ Researcher scored participant’s fourth worksheet and calculated DCPM and EPM

Appendix F

Math problem worksheet previewing

___ Researcher handed participant unsolved math worksheet

___ Research showed the participant a worksheet with the same problems solved showing work (answer key)

___ Researcher used the answer key worksheet to explain to the participant the steps involved in solving each problem and the final answer to “x” and “y” (e.g. “you will use substitution/subtraction/addition/multiplication/elimination to solve this problem.” “This is an elimination problem, so I multiply this quantity _____ by 4 to get the quantity _____.....”)

___ After describing steps to solve each problem, the research removed the answer key from the participant’s workspace in front of him/her

___ Researcher directed the participant’s attention to his/her unsolved math worksheet

___ Researcher said to the participant “You will have five minutes to complete this worksheet, please solve for X and Y. Try to solve as many problems as you can within the time limit. When I tell you to stop, please put your pencil down.”

___ Researcher started stop watch as soon as participant began worksheet

___ Researcher stopped stop watch after 5 minutes

___ Research told participant to stop working after 5 minutes had elapsed

___ Researcher scored participant's worksheet and calculated DCPM and EPM

Appendix G

Immediate Corrective Feedback (ICF)

___ Researcher handed math worksheet to participant

___ Researcher said to the participant “Please solve for X and Y. If you come to a problem you don't know how to solve, or you give an incorrect answer, I will tell you how to solve it.”

___ When/if the participant did not respond to a problem within 10 seconds, the researcher showed the participant how to solve the problem.

___ When/if the participant wrote an incorrect numeral on the worksheet (i.e. the participant made an arithmetic error) or if the participant arrived at the incorrect answer the researcher pointed to the incorrect answer, identified the mistake and told the participant how to solve for the correct answer.

___ The researcher instructed the participant to work the next problem until all 10 problems were complete.

___ Researcher handed participant a new worksheet with 10 unsolved problems

___ The researcher instructed the participant to complete these 10 problems without assistance

___ Researcher started stop watch as soon as participant began worksheet

___ Researcher stopped stop watch after 5 minutes

___ Research told participant to stop working after 5 minutes had elapsed

___ Researcher scored participant's worksheet and calculated DCPM and EPM

Appendix H

	<i>True</i>			Not True
1. This intervention to improve my math skills was fair.	3	2	1	0
2. My interventionist gave me enough time to practice math.	3	2	1	0
3. This intervention is good one to use with other students.	3	2	1	0
4. I like this intervention for my math skills.	3	2	1	0
5. I think this intervention helps me do better in school.	3	2	1	0
6. I feel I am good at math.	3	2	1	0
7. I feel I am as smart as my classmates.	3	2	1	0
8. I feel I can do math problems quickly.	3	2	1	0
9. I feel I can memorize math problems easily.	3	2	1	0
10. I feel I can figure out the answers almost always.	3	2	1	0